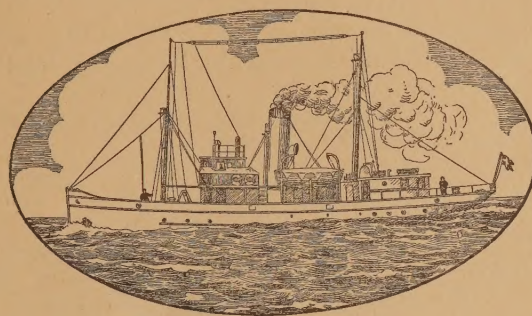


Report
of
The Danish Biological Station
to
The Ministry of Fisheries



No. 52

By
H. Blegvad, Ph. D.
Director

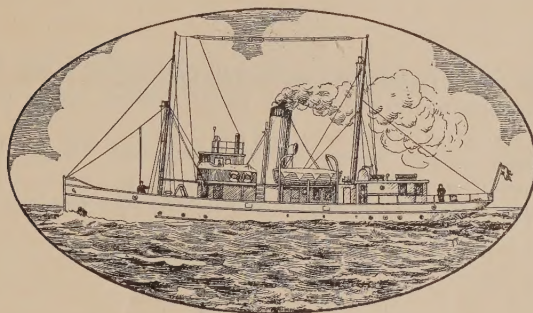
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1950.

The Reports from the Danish Biological Station (Nos. I—XXI) are published in the official Danish "Fiskeri-Beretning" for the years 1890—91 until 1912. After this year they appear as special publications. The Reports I—XXXII are edited by Dr. C. G. Joh. Petersen, the Reports XXXIII—XXXVI by Dr. A. C. Johansen and the later Reports by Dr. H. Blegvad.

- I. *C. G. Joh. Petersen*: Fiskenes biologiske Forhold i Holbæk Fjord. (1890—91)* 63 pp. 1 Chart. Out of print.
- II. *Idem*: On the Eggs and Breeding of our Gobiidæ. (1891—92.) 9 pp. Two Plates. Out of print.
- III. *Idem*: The Pelagic Life in Fænø Sound etc. (1892—93.) 38 pp. Tables. Out of print.
- IV. *Idem*: On the Biology of our Flat-fishes and on the decrease of our Flat-fish Fisheries. (1893—94.) 146 pp. 2 Plates. 1 Chart. Many Tables. Out of print.
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- VI. *Idem*: The Yearly Immigration of young Plaice into the Limfjord etc. (1895—96). 48 pp. 1 Chart. 2 Tables. Out of print.
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- XVII. *C. G. Joh. Petersen*: II. Second Report on the Oyster and Oyster Fisheries in the Lim Fjord. 1908. (24 pp).
- XVIII. *C. G. Joh. Petersen*: I. The Yield of the Limfjord fisheries in recent years and the transplantation of Plaice in 1908. With 6 tables and 1 Chart. II. Biological investigations on the stock of Plaice in the Limfjord. With 3 Tables. III. The Yield of the Prawn fishery from 1885—1907 and its improvement by means of protection. With 3 Tables. 25 pp. 1909.
- XIX. *Idem*: Some Experiments on the Possibility of combating the harmful Animals of the Fisheries, especially the Whelks in the Limfjord. 20 pp. 1911.
- XX. *C. G. Joh. Petersen* og *P. Boysen Jensen*: Valuation of the Sea. I. Animal Life of the Sea-Bottom, its food and quantity. With 6 Tables, 3 Charts and 6 Plates. 81 pp. 1911.
- XXI. *C. G. Joh. Petersen*: Valuation of the Sea. II. The Animal Communities of the Sea Bottom and their importance for marine Zoogeography. With 6 Plates, 3 Charts and an Appendix. 110 pp. 1913.
- XXII. I. *P. Boysen Jensen*: Studies concerning the organic matter of the Sea Bottom. II. *H. Blegvad*: Food and Conditions of Nourishment among the Communities of invertebrate animals found on or in the sea bottom in Danish waters. III. *C. G. Joh. Petersen*: The Work of the Biological Station from 1889—1914. With Illustrations and Tables.

*) The figures in () refer to the "Fiskeri-Beretning" for the years quoted.

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Introduction.

The sprat occurs from the Black Sea through the Mediterranean and along the western coast of Europe up to the Lofoten. It is also found at the Faroes, but not at Iceland or Greenland. It lives in all Danish waters and goes far into the Baltic, but is rare in the Gulf of Bothnia, the northern area of this water. In other words the principal occurrence of the sprat falls south of our waters in somewhat warmer seas, which goes well with the fact that beside eel and sole it is one of the most stenothermous fishes of this country. It suffers much from severe winters, and during the severe ice-winters of 1940—42 considerable quantities of dead sprat were observed in several Danish localities, for instance in the Limfjord. Similar observations were made after earlier severe ice-winters, for instance in 1929¹⁾

The sprat fishery is of old date in this country. For nearly a century it has been an important fishery in the Limfjord²⁾. In older times the sprat were mostly used for bait or for smoking; nowadays they are hardly used as bait. Many sprat are still smoked, but most of them are now tinned.

A rapid development of the sprat fishery has been going on in this country for more than 25 years: the sprat are now caught by means of trawls or otter seines, so that the fishery can now be pursued within much larger areas than formerly when only shore seines, weels or pound nets were used. At that time the sprat fishery nearly exclusively took place in fjords and coastal waters, but now it is also carried on extensively in the open waters, for instance in the Skagerak and the Kattegat.

During the latest 6 years reported on by "Fiskeriberetningen" the catch yields were as follows:

¹⁾ A. C. Johansen: Mortality among Porpoises, Fish and the Larger Crustaceans in the Waters around Denmark in Severe Winters. Rep. Dan. Biol. Stat. XXXV, 1929.

²⁾ Erik M. Poulsen: Seine Fishery for Small Herring and Sprat in the Limfjord. Rep. Dan. Biol. Stat. XLIX, 1948.

	tons	1000 kr.	øre per kg	value in per cent. of the total fishery
1942	3 100	1 300	42	0.9
1943	5 600	2 100	38	1.3
1944	11 472	4 487	39	2.7
1945	1 764	716	41	0.5
1946	3 677	1 243	34	0.5
1947	3 792	1 284	34	0.7

It appears from these figures that there have been comparatively great fluctuations in the fishery, from 11.000 tons in 1944 to less than 2.000 tons in 1945. For the years 1946 and 47 we find the following average catches in tons in our different waters (together with their values and prices in øre per kg):

	tons	1000 kr.	øre per kg
The North Sea	0	..	..
The Skagerak	1 203	334	28
The Kattegat	1 756	588	34
The Sound	0	..	..
The Belt Sea	462	201	44
The western Baltic	24	12	50
The true Baltic	0	..	..
The Ringkøbing Fjord	1	0.5	42
The Limfjord	289	129	45

It is seen that by far the heaviest catches are made in the Kattegat and the Skagerak; after these waters follow the Belt Sea and the Limfjord, and in the western Baltic and the Ringkøbing Fjord the yields are much smaller. In the true Baltic, the North Sea and the Sound there is hardly any fishing of sprat though there are large quantities of sprat in these waters: Swedish and German fishermen carry on a considerable sprat fishery in the Baltic. During Danish fishing experiments in the North Sea large quantities of sprat were taken along the eastern edge of the Dogger Bank.

There is some variation from one water to the other in the prices fetched by the sprat. In the Limfjord, the Ringkøbing Fjord, the Belt Sea and

the western Baltic the price is nearly twice as high as in the Skagerak and nearly $\frac{1}{3}$ higher than in the Kattegat. The cause of this is the fact that the sprat of the Skagerak and the northern Kattegat are comparatively lean.

Apart from the catches mentioned above comparatively large quantities of sprat are taken for purely industrial purposes; they are used either at the pond farms or for the production of fish-meal.

I. The sprat fishery.

A. Catching gears.

The gears used in the sprat fishery are nearly exclusively seines, i. e. Danish seines and otter seines; the larger otter seines are often termed trawls. Also shore seines are used occasionally, and small quantities of sprat are now and then taken in pound nets or eel seines.

The sprat seine (Danish seine) is used only in the Limfjord. By way of preventing too great a damage to the young of other food-fishes, particularly flatfish, certain regulations limit the dimensions and the use of the seines: The meshes of the arms and the front part of the bag must not be less than 39 mm square, those of the cod-end not less than 10 mm; the maximum length of the warp of each arm is 700 m. The fishery must not take place outside the period 1/XI—15/IV and not in the central and western part of Nissum Bredning.

In the course of years the use of the sprat seine decreased very much: it was to a rising degree, replaced by the sprat trawl (otter seine), which is, and for some years has been extensively used for the catching of sprat in the Belt Sea.

The use of the sprat trawl in Danish waters is limited by the following regulations: the span of the gear along the head-rope must not exceed 19 m; the mesh-width of the trawl must nowhere be less than 14 mm; the weights must be attached by means of straps; and within the three-mile limit, with a few exceptions, it is not allowed to spread the gear by means of a second boat. In the Limfjord the use of this gear is permitted between 1/X and 31/III, in the rest of our waters between 1/X and 15/IV.

Outside the three-mile-limit much larger trawls with a span of up to 40 m are being used during recent years; these large trawls are often spread by means of a second boat, in which case they are termed "twin trawls".

Shore seines are used occasionally, for instance in the Limfjord, at Hvide Sande, at certain localities of the north and east of Jutland, and in the Lesser

Belt. Purse seines are hardly in use any longer for the catching of sprat; in former times they were used to some extent in the Skagerak, at Anholt and in the Isefjord, and sprat were also taken during the herring fishery with purse seines in various localities of the Belt Sea. In the Limfjord some sprat are caught here and there in set nets. Instead of special sprat trawls the fishermen of Skagen use herring trawls with a small-meshed cod-end.

The changes during recent years in the sprat fishery, resulting from the introduction of trawls or otter seines, have brought about a considerable intensification of this fishery. It can hardly be decided at present whether or not the regulations on trawl fishery introduced for the protection of the stock will prove sufficient.

B. Catching areas.

The map figure 1 shows the principal catching areas of sprat in Danish waters — mostly based on information received from the Fishery Patrol through the Ministry of Fisheries.

In the North Sea the sprat fishery is very limited: small amounts are taken now and then in shore seines N. and S. of Hvide Sande; inconsiderable quantities are also caught in the Ringkøbing Fjord. As mentioned, however, large quantities of sprat occur in the open North Sea, so that it is possible to increase the sprat fishery in this water.

In the Skagerak the fishery is pursued at depths between 30 and 100 m from NW. of Hirtshals to NE. of Skagen. Here it is no doubt possible to extend the fishery in a westward direction. At the coast between Skagen and Løkken a less important sprat fishery with shore seines continued down to 1946, in which year the imposition of a protection of the sprat during the summer season stopped this fishery.

In the northern Kattegat the fishery covers a vast area between Skagen, Læsø and Sæby at depths between 15 and 60 m. In winter the sprat migrate from shallower into somewhat deeper and warmer



Fig. 1. Situations of the principal catching areas of sprat in Danish waters.

water, and during this season the fishery therefore takes place principally within the northern and eastern sections of the area. Off Frederikshavn the largest quantities in September are taken in shallow water of 12–14 m depth, but in the course of the autumn the catching areas shift in an easterly direction, and in December the heaviest catches are taken at a depth of about 30 m.

The area between Læsø and Skagen together with the adjacent parts of the Skagerak constitute the area from which the heaviest catches of sprat are landed in Danish waters.

In the central part of the Kattegat the sprat fishery is of slight importance; occasionally, small amounts are taken in pound nets and eel seines within the coastal waters, particularly the fjords. In former years small-meshed seines also took some sprat in the water round Anholt.

The southern Kattegat is another more important sprat area, and here the fish are taken nearly exclusively by means of sprat seines or the larger sprat trawls, which outside the three-mile-limit are mostly used as twin trawls. The fishery takes place particularly in the channels between Djursland and Sjællands Odde and within a vast area between the north coast of Sealand and the neighbourhood of Anholt.

The best catching areas are situated N. of Lysegrunden. In the Isefjord the sprat fishery mostly takes place in autumn. Sprat can also be taken here in mild winters; but in cold winters there are no sprat in the Isefjord, apparently because the fish then emigrates from the fjord into the deeper and therefore warmer water of the Kattegat.

In the Sound there is no sprat fishery. This is no doubt exclusively due to the existing prohibition of seine fishery in the Sound, for the sprat is found throughout this water.

In the Belt Sea the sprat fishery takes place nearly everywhere, more particularly outside the 20 m curve. The most important catching areas are found in the Århus bay, N. of Funen, in the northern part of the Great Belt and the southern part of the Lesser Belt. Here as elsewhere the fishery shifts to deeper water during the coldest season.

In the western Baltic the most extensive sprat fishery is practised in the outer part of the Flensborg Fjord, S. of Als and Ærø. S. of Lolland there is hardly any sprat fishery.

In the true Baltic the fishery is unimportant: there are occasional landings from about Kriegers Flak, Hjelmsbugten and Kadetrenden. However, the sprat is frequent throughout the Baltic, and so it should be possible to intensify the fishery in this water.

In the central part of the Limfjord there is an extensive sprat fishery throughout the winter. The fishery takes place particularly in somewhat deeper water, more especially in the sounds and the narrows between the broads because the sprat emigrates from the shallows as soon as the water cools down.

C. Seasonal fluctuations of the fishery.

Of course the progress of the fishery to a high degree depends on the protective regulations, which permit fishery with sprat seines in the Limfjord only between 1/XI and 15/IV and with sprat trawls in the rest of our waters only between 1/X and 31/III. These regulations have been in force for 10–15 years; from 1946 another regulation prohibited the landing of sprat between 15/IV and 30/IX, but the latter modification was repealed later on. Before the prohibition of 1946 sprat were also caught during the summer months, especially in July and August. This summer fishery was of particular importance in the Belt Sea where it was carried out with otter seines

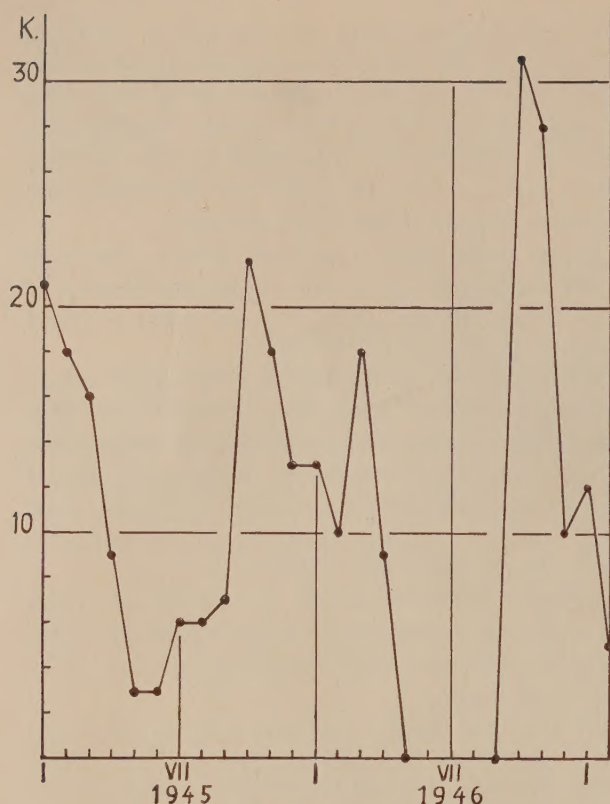


Fig. 2. The progress of the sprat fishery in the individual months, characterised by the sum of "marks" from the various districts of the Fishery Patrol (cp. the text p. 8).

and twin trawls. In other places, for instance at the west and south coasts of the Kattegat, some sprat were taken in pound nets throughout the summer, and at the west coast of Jutland shore seines were often used during the same season.

The monthly reports on the fishery from the controlling stations to the ministry give an idea of the progress of the fishery throughout the year. Figure 2 illustrates the course of the fishery, basing on information from 20 controlling stations within the areas in which sprat are the object of fishery. The controlling stations do not give exact figures for the catch yields, but the reports tell whether the fishery has been good, middling, poor, etc. These pieces of information were collected and given a "mark" from 0 to 6, 0 denoting that there has been no fishery or that it gave no yield, 6 that the catches were exceptionally heavy. The figure gives the sum of these marks for each month between January 1945 and February 1947.

It appears distinctly from the figure that in both

years the winter half-year gave by far the greatest yields, which concentrate on the months of October, November and March, a small reduction of the yields occurring during the proper winter time. It further appears that in May—September, 1946 no sprat at all were landed, but in 1945, when it was not prohibited to land sprat during these months, small quantities of sprat were taken, not so much in May—July as in August—September.

From the great fishing harbours of Hirtshals, Skagen and Frederikshavn we have direct statistics on the landings in the individual months of the year. The following figures give the catches in metric tons at these harbours for each month of 1944 (before it was prohibited to land sprat between May and August) and of 1947 when the prohibition of landing was still in force.

	Hirtshals		Skagen		Frederikshavn	
	1944	1947	1944	1947	1944	1947
Jan.	0	2	364	131	219	15
Feb.	22	422	90	66	1	0
March.....	39	152	1 295	340	122	0
April.....	0	108	2 059	763	4	8
May.....	0	0	1 172	0	4	0
June.....	57	0	10	0	0	0
July.....	457	0	3	0	0	0
Aug.....	1 005	0	246	0	16	0
Sept.....	19	19	100	0	0	3
Oct.....	0	21	6	362	9	1
Nov.....	0	2	54	474	15	23
Dec.....	0	1	128	39	11	69

Before the introduction of the close season in summer there was a rather considerable sprat fishery in the summer months of July and August, and besides this there was an important fishing season during the winter months and in early spring. After the imposition of the close season the summer fishery of course stopped, and there is a comparatively uniform distribution of the fishery between October and April.

Apart from the effects of the close season and the influence of the weather on the fishery the heterogeneity of the catches of sprat throughout the year is mainly caused by the fact that the nutrition of the sprat, and hence its suitability as a raw material of the tinning industry, is subject to great seasonal fluctuations. The sprat spawns in late spring and early summer (April—June), and during this period it is quite unfit for tinning purposes and not very suitable for other purposes. Later in summer it

attains a better state of nutrition, the highest fatness occurring in August—September. Nevertheless the sprat caught at this time of the year are also unfit for tinning purposes because their stomachs are full of food, which makes the fish less preservable and difficult to tin. During the winter half-year, it is true, the sprat is no longer so fat, but as it eats little at this time it is an excellent object of tinning, and from November to March the tinning industry buys up large quantities of the catches. The highest prices are therefore fetched during these months, in 1945 for instance 31—80 øre per kg

against only 18—27 øre per kg in April—October of the same year; in 1944 the corresponding prices were 32—75 øre per kg in November—March against only 20—32 øre per kg in April—October.

From an economical point of view a close season from April to September in other words would be highly expedient, and the fact that the spawning time of the sprat, May—June, also occurs within this period makes the close season — at any rate the former half of it — desirable also from biological causes.

II. Spawning and migrations.

In Danish waters the sprat spawns in late spring and the first part of early summer. In weekly hauls with the Hensen net (in 1929—43) from the three light-vessels Anholt Knob (central Kattegat), Schultz' Grund (south-western Kattegat) and Halskov Rev (Great Belt) eggs of sprat were taken from the middle of April till the middle of August; within this period the great majority of eggs were taken in April—May (P. Heegaard 1947¹). At all three light-vessels very few eggs were taken, which shows that the proper spawning of the sprat are not situated near these light-vessels. Also the catches of larvae were small. Figure 3 gives the total numbers of larvae taken at the three light-vessels in the individual months of the years 1929—43. Most larvae were taken at the Anholt light-vessel, the numbers from Schultz' Grund and Halskov Rev being much inferior. At Anholt Knob larvae were taken from May till July: in May they were few in number, in June the quantity was highest, and somewhat fewer occurred in July; larvae were not found later than July. At Schultz' Grund larvae were also taken between May and July, but here the majority occurred in July. At Halskov Rev larvae were observed from March till July; as was the case at Schultz' Grund the majority of larvae were taken in July. The fact that many larvae are taken in June and July but none whatever in August (or later on) seems to indicate that the development of the larvae during the warm summer season here takes place very rapidly.

¹) P. Heegaard: Investigations on the Breeding Season and the Quantities of Eggs of the Food-Fishes of the Kattegat and the Northern Belt Sea. 1929—41. Medd. Komm. f. Danmarks Fiskeri og Havunders. Ser. Fiskeri-, Bd. XI, 4. 1947.

The spawning in the Limfjord was discussed by A. C. Johansen²). The spawning season falls within the period April—July. Investigations at the beginning of May 1930 brought out sprat eggs throughout the fjord. Most eggs were found in Livø Bredning, much fewer occurring in the other broads, and only quite a few eggs were taken in the narrow eastern part of the fjord. The continuation of the spawning at any rate till the beginning of July appears from the fact that A. C. Johansen in a sample of sprat collected in Hvalpsund on 23. June found both spent and spawning individuals, males as well as females.

There are course some fluctuations from year to year in the extent of spawning. In 1932 the number of eggs were examined at the beginning of May, i. e. at the same time as in 1930; the same gear was used (the Hensen net). The two examinations gave the following mean numbers of eggs per 1 m²):

Area ¹)	1930	1932
A West. Limfjord...	13	54
B Centr. » ...	45	143
C East » ...	1	6

In other words the eggs taken in 1932 were thrice as numerous as in 1930, but their distribution through the fjord was nearly the same as in 1930.

The map figure 4 gives the quantities of eggs taken in the individual hauls. The great majority of eggs were taken in Livø Bredning, but many eggs also occurred in Thisted and Visby Bredning, in

²) A. C. Johansen: The sprat (*Clupea sprattus* L.) in the Limfjord. Rep. Dan. Biol. Stat. XXXVI, 1930.

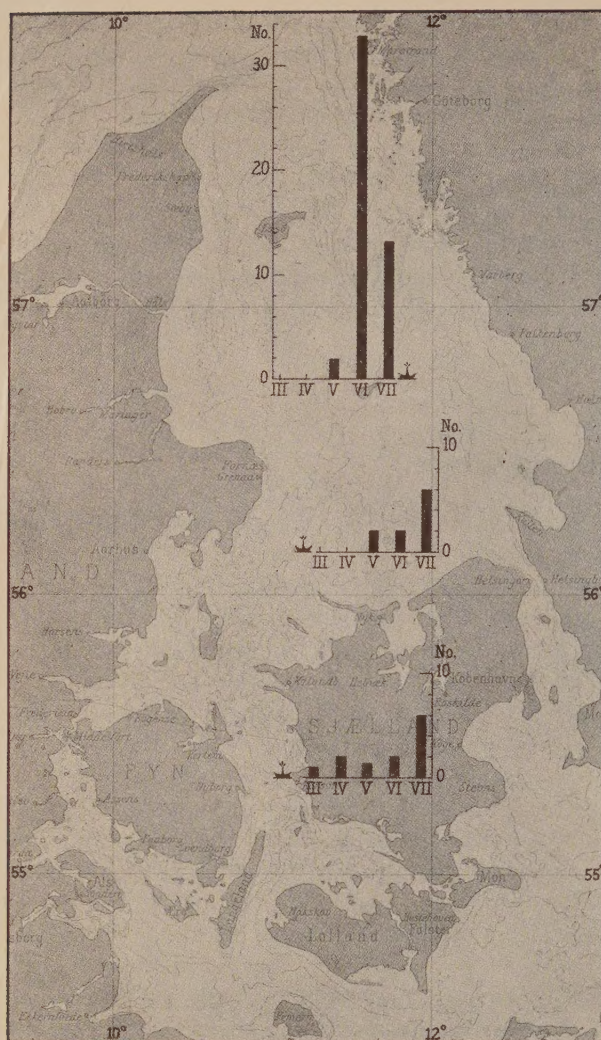


Fig. 3. The total numbers of sprat larvae taken in different months in vertical hauls with the Hensen net from the light-vessels of Anholt Knob, Schultz' Grund and Halskov Rev in 1929—43.

III. Size and growth of the sprat.

On account of the catching methods (seines or trawls) the sprat of the material at hand had lost nearly all scales, so that it was impossible to carry out age determinations. For this reason only some scattered observations can be given. A. C. Johansen (l. c.) brings some information on the growth of the sprat in the Limfjord. Sprat of a little more than 3 months, taken in the ring trawl and measured at the beginning of September have a length of

Sallingsund, Kås Bredning, Venø Bugt and Lavbjerg Bredning. Eggs were few, however, in Nissum Bredning and in the water E. of Salling; in the narrow part of the Limfjord E. of Løgstør the amount of eggs was quite inferior. Within rather narrow limits there may be considerable variations in the number of eggs: in one locality of Livø Bredning 1314 eggs were taken per 1 m², while two other localities, only about 4 naut. miles away, yielded only 9 and 13 eggs.

Samplings with the Hensen net in the Limfjord earlier in the year (Jan. 19.—26. and March 17.—22., 1945) gave neither eggs nor larvae of sprat.

In all probability the migrations of the sprat do not cover great distances, and there are no observations to the effect that it makes such long migrations as the herring, its close relative; but it makes shorter seasonal migrations, apparently caused by the changes in the temperature of the sea water. As mentioned the fishery in various localities led to observations of emigrations from the shallower water in winter. In the Limfjord, for instance, the sprat in winter emigrates from the shallower broads (5—10 m) into the narrow channels with comparatively deep water (15—20 m). It was also observed that the sprat of the shallow Isefjord in winter emigrates into the deeper water of the southern Kattegat, and the fact that this emigration takes place particularly in the severe winters shows that this migration is caused by the temperature. As a warm water fish the sprat in winter leaves the highly cooled coastal waters and goes into deeper waters with lesser falls of temperature.

When the water grows warmer in the course of spring, the sprat again returns to shallower water.

about 3 cm (29 mm, 50 inds.). A sample taken at the end of August in the more wide-meshed, bottom-trailing eel seine, showed a somewhat higher mean length of the 0-Gr., 5.5 cm; in another sample from the end of August the mean length of the 1-year-old sprat was about 9 cm while a few still older sprat with 2 or 3 zones in their scales measured 9.5—12 cm. A. C. Johansen moreover calls attention to the fact that age determinations from the scales of sprat may

be somewhat uncertain, partly because secondary zones occur comparatively frequently, partly because the smallest sprat of the 0-Gr. in all likelihood often do not form scales before the beginning of the winter.

In samles from the commercial fishery of the Limfjord the sprat—because they are sorted by the mesh-width of the gears—will rarely be divisible into size groups. The following table shows the few cases in which size groups appeared in the material.

These measurements show that the sprat of the Limfjord at the end of the year fall into two size groups, one with a mean length of about 7.5 cm and another with a mean length of about 10.5 cm.

Dato cm	9/11	9/11	20/11	21/11	10/12	10/12	16/12	5/1	15/2
5	1	1	..	..	..	..	..	..	..
6	2	2	3	5	2	12	..	32	..
7	6	31	10	11	36	14	47	28	112
8	37	55	4	25	36	11	6	140	67
9	17	11	45	11	22	10	23	90	15
10	125	85	125	12	47	29	76	4	24
11	82	89	69	22	25	29	9	28	10
12	19	19	2	10	6	2	3	29	..
13	1	..	..	..	..	..	2	3	..

In view of the fact that A. C. Johansen at the end of August found the 0-Gr. (the sprat of barely 6 months) to be 5.5 cm and the I-Gr. (those of barely 18 months) to be about 9 cm long, it may be taken



Fig. 4. Numbers of sprat eggs taken in the Limfjord per 1 m in vertical hauls with the Hensen net from bottom to surface between May 6.—9., 1932.

that the size groups found here correspond to the 0- and I-Gr. thus denoting the length of the sprat at the end of the first and the second growth season. The bigger size group, however, does not exclusively consist of I-Gr. individuals, but also of some II-Gr. individuals (with 2 winter zones): in a small number of sprat between 11 and 13 cm in length 2 winter zones were counted in the scales; in quite a few bigger sprat A. C. Johansen found 3 winter zones. In other words the sprat of the Limfjord seem to be able to attain an age of nearly 4 years. Basing on these investigations the lengths at the end of the successive years may be given as:

1 year	7 cm
2 year	10 -
3 year	12 -

By way of comparison it may be stated that A. Molander¹⁾ in sprat from the fjords of the west coast of Sweden found a mean length of about 11 cm in barely 2-years-old and about 12 cm in barely 3-years-old sprat.

cm	Skagerak + northern Kattegat	Southern Kattegat + Belt Sea	Limfjord	
			otter seine	Danish seine
4	..	..	1	..
5	..	1	25	..
6	1	11	290	13
7	20	31	834	209
8	53	111	1 004	746
9	79	296	541	332
10	249	254	729	674
11	357	119	436	905
12	181	281	121	310
13	175	203	10	14
14	98	58	..	..
15	43	8	1	..
16	20	..	..	..
Number	1 276	1 373	3 992	3 203
m.lgth.	11.4	10.7	8.6	9.7
g per ind.	10.7	12.2	5.9	8.4

The size at which the sprat are caught varies somewhat from one water to the other as will appear from the table above:

H. Blegvad²⁾ points out that the sprat of the Skagerak + the northern Kattegat are somewhat bigger than in our southern waters, but that the mean weight is lower. It is seen from the table above that the mean length and mean weight of the Limfjord sprat are lower than in the other two areas of water. But within the same size group the Limfjord sprat is nearly as heavy as the Belt Sea sprat, which appears from the following analyses of Limfjord sprat principally containing bigger sprat and with a mean length corresponding to those found in the Belt Sea and the Skagerak:

Samples from 1939/40 (1248 ind.):	m.lgth. 10.8 cm, m. weight 12.7 g
Sample from 9/XI-1940 (287 ind.):	m.lgth. 10.7 cm, m. weight 9.1 g
Sample from 1942 (72 ind.):	m.lgth. 10.3 cm, m. weight 11.1 g

A calculation of the coefficient of nutrition

$$\left(k = \frac{100 \text{ g}}{l^3} \right)$$

from the mean figures of the table for length and weight per 1 ind. of the 3 areas gives the result that the coefficient of nutrition in the Limfjord sprat is nearly as high as that of the Belt Sea sprat:

Belt Sea + south. Kattegat.....	k = 0.99
Limfjord, otter seine.....	k = 0.93
— Danish seine	k = 0.95
Skagerak + north. Kattegat	k = 0.72

Also the price per kg of sprat varies in comparatively good accordance with the coefficient of nutrition; in 1947 the prices in øre were as follows:

Belt Sea + west. Baltic	47 øre
Limfjord	45 -
Skagerak + north. Kattegat	31 -

IV. Parasites.

On the sprat we often find two parasitic crustacea (copepods). The head of their cylindrical, pale-green, 2 cm long and about 2 mm thick body is buried in

¹⁾ Arvid R. Molander: A Research upon the Sprat of the West Coast of Sweden. I. Svenska Hydr.-Biol. Kom. Skr. Ny Ser. Biologi. II, 4. 1940.

the body of the sprat. Trailing from their tail-end we often observe two several cm long, thin, green filaments; they are full of the eggs of the parasite.

²⁾ H Blegvad: On the Waste Fish Fishery. Rep. Dan. Biol. Stat. XLVIII, 1945.

One species, *Lernaeenicussprattae*, bores its way into the eye, the other, *L. encrasichola*, into the body.

These two parasites were found on the following percentages of sprat from various Danish waters:

	No. of sprat examined	Percent. no. of sprat with <i>L. sprattae</i> <i>L. encrasichola</i>	
Skagerak + north. Kattegat	1.307	1.5	0.8
Limfjord	2.351	1.3	0.7
South. Kattegat	755	0.6	0.2
Belt Sea	1.347	1.2	0.6
True Baltic	215	0	0

In other words nearly 2 per cent. of our sprat are

infested with these parasites. *L. sprattae* is twice as frequent as *L. encrasichola*. Both species seem to be more frequent in our northern than in our southern waters. In the true Baltic the parasites were not observed, but this may be merely accidental because only a small number of sprat from this water were examined.

The highest number of parasites observed on one sprat is 9. This sprat was very lean: it weighed only 11 g while other sprat of identical length from the same sample weighed about 18 g. This means that the damage done to the sprat by these parasites may be rather considerable.

V. Racial analyses.

Various species of fish—for instance the important food-fishes cod, plaice and herring—have been found to include different races, which can be distinguished by somewhat differing numbers of vertebrae, fin rays and keeled scales; 'keeled scales' is the term for the tile-shaped scales forming the ventral edge or 'keel' in fishes of the herring family. In countings for race analyses we only use the row from the ventral fins to the vent; this row is termed K_2 . Besides in structural features the races also differ in various biological features, such as distribution, spawning localities or spawning seasons. In the North Sea for instance we find a plaice race in which the mean number of anal fin rays is 54 while our belts contain another race with a mean number of 50. In the individual specimens of the North Sea race the number of fin rays ranges between 47 and 63 (counted in 4504 ind.); in the Belt Sea race the figures are 43 and 57 (1888 ind.)¹⁾. One individual can therefore rarely be traced to one race or the other. The racial difference does not appear until a large number of individuals are counted.

However, the numerous race analyses carried out during recent years have shown that these numerical characters of one race are not fixed and invariable, but are subject to variations from year to year. Countings in plaice of the North Sea race, carried out in specimens from the west coast of Jutland, have proved that there may be some variation from one year-class to another in the number of anal

fin rays: the 1932 year-class (i. e. plaice born in this year) had a mean number of 54.7 rays while the 1941 year-class showed a mean of only 53.0 rays²⁾. Moreover tank experiments³⁾ have proved that the young of the same parents (sea-trout) get somewhat differing numbers of vertebrae if they are hatched at different temperatures. The natural consequence of these observations is that distinctions between races on the basis of small differences in mean numbers of fin rays, vertebrae and keeled scales must be made with great care. We are highly in need of more detailed investigations on the variability of the numerical race characters. The whole problem of race is also of practical importance because race investigations are often or have often been used for determinations of the migrations of the fish populations.

As regards the sprat A. Molander⁴⁾ has carried out detailed researches on the variation of the mean number of vertebrae in populations from various parts of the Swedish coast of the Skagerak. In comparing the numbers of vertebrae with the growth he finds that there are different milieu-types—a sea-type, a skärgård-type, and a fjord-type—to be distinguished from one another by certain differences

²⁾ Erik M. Poulsen: Yearly variations in the number of Anal Fin Rays of the Plaice in the Thyborøn Area. Ann. Biol. III, p. 98, Cons. perm. intern. pour l'expl. de la mer. 1948.

³⁾ Å. Vedel Tåning: Experiments on meristic and other characters in Fishes I. Medd. fra Komm. for Danmarks Fiskeri- og Havunders. Ser. Fiskeri XL, 3, 1944.

⁴⁾ A. Molander: A Research upon the sprat of the West Coast of Sweden. I. Svenska Hydr.-Biol. Kom. Skr. Ny Ser. Biologi. II, 4, 1940.

¹⁾ Erik M. Poulsen: On the Migrations and the Racial Character of the Plaice. Rep. Dan. Biol. Stat. XLIII, 1939.

of growth rate and numbers of vertebrae. The spawning areas of these different types cannot be distinguished from each other, and migrations of sprat take place to and from the different areas; therefore Molander is of opinion that these types cannot be interpreted as different races, but should only be considered the products of the influence of different external conditions on the young during their development.

During the investigations on sprat from Danish waters carried out during recent years a large number of fish have been examined from various areas between the Skagerak and the true Baltic E. of Møn. Moreover a sample of sprat from the Stockholm Skärgård has been examined; it was most kindly put at my disposal by Dr. Hessle (Kungl. svenska Lantbruksstyrelsen).

Most of the Danish material was taken in trawls (often during fishings for herring or fish for processing). In the great majority of cases the sprat on account of the catching method and the following transport and sorting had lost all scales; so it was impossible to make an age determination of the sprat examined, and a grouping of the fish into age groups and year-classes had to be given up.

The material was measured and the vertebrae and keeled scales (K_2) were counted. The vertebrae of the body (*vertebrae praecaudales*) and the tail (*vertebrae caudales*) were counted separately. The urostyle, which consists of the hindmost caudal vertebrae, was counted as one vertebrae.

A. Anomalies of the vertebral column.

In the sprat—as in a number of other fishes—anomalies now and then occur in the vertebral column. These anomalies appear in the fact that 2, rarely more vertebrae are not separated from each other in the normal way but are more or less fused. The term ‘fused vertebrae’ does not mean that vertebrae once separated have grown together during their development, but only that the vertebrae in question are not so well distinguished as normal vertebrae. Individuals with such fused vertebrae were not included in the calculation of the mean number of vertebrae not even when it was possible to count the number of fused vertebrae.

Of the 6964 sprat from Danish waters in which the vertebrae were counted 82 individuals or 1.2 per cent. of the sprat had fused vertebrae.

There is some variation from one water to the other in the percental occurrence of individuals with fused vertebrae; this appears from the following percentages:

	No. of ind. examined	Percentage
Skagerak + north. Kattegat	1.807	0.2
South. Kattegat	450	0.2
Isefjord	350	0.3
Mariager Fjord.....	104	1.0
Limfjord	2.461	1.5
North. Belt Sea	1.118	2.2
West. part of true Baltic	213	1.5
Stockholm Skärgård	76	11.8

In the Skagerak and the Kattegat we find very few individuals with fused vertebrae, only 0.2 per cent. In the Isefjord the percentage is slightly higher with 0.3 per cent., in the Mariager Fjord somewhat higher with 1.0 per cent. In the Limfjord the percentage of sprat with fused vertebrae rises to 1.5, in the Belt Sea to 2.2. The small sample from Kriegers Flak in the true Baltic shows a percentage of 1.5. Far back in the Baltic, however, the individuals with fused vertebrae are much more frequent; in samples from the Stockholm Skärgård the percentage was no less than 11.8.

The fact that the percentage of individuals with fused vertebrae rises in a southerly and easterly direction through the Danish waters and into the Baltic was observed also in cod and plaice. Anomalies of the vertebral column were studied in particular by R. Kändler¹⁾, who is of opinion that the anomalies are caused by unfavourable conditions of living; this view is based on the observation that the most frequent anomalies occur in populations of different salt water fishes living in the inner Baltic, i. e. near their limit of distribution towards the brackish water. The fact that by far the highest percentage of sprat with anomalous vertebrae is found in the Stockholm Skärgård or near the inner limit of the sprat in the Baltic is highly in favour of this supposition. But on the other hand the considerable rise in the number of individuals with fused vertebrae from the Skagerak-Kattegat to the Belt Sea-Limfjord, from 0.2 to about 2 per cent., seems to indicate that unfavourable conditions of living alone are not the cause of the fusions; for there is no reason to believe that the sprat of the Belt Sea live under poorer conditions than those of

¹⁾ R. Kändler: Unsicherheiten bei Bestimmung der Wirbelzahl infolge Verwachsungserscheinungen. Journ. du Cons. Int. pour l'expl. de la mer VII. 1932.

the Skagerak and the Kattegat. On the contrary the sprat of the Belt Sea generally speaking shows a better state of nutrition and reaches the same size as the sprat of the Skagerak and the northern Kattegat. It is perhaps a more obvious possibility that we here find a direct influence from the degree of salinity because the number of anomalies rises with the decrease of the salinity:

	Percentage of individuals with anomalies	Salinity in per mille, 20 m depth
Skagerak + north. Kattegat ...	0.2	32
Limfjord	1.5	28
Belt Sea	2.2	25
Stockholm Skärgård	11.8	7

The anomalies are not equally distributed through the vertebral column. For each vertebrae of the pre-caudal and caudal part of the vertebrae column table 1 gives the number of anomalous vertebrae and the quantity of vertebrae of the serial number in question for the whole of the Danish material, and in the right-hand column of the table we find the frequencies of anomalous vertebrae in percentages of the total number.

It appears from the table that nearly all vertebrae are liable to show anomalies. In the material examined, which totals about 6.700 sprat, anomalies were found in all precaudal vertebrae with the exception of nos. 15—16 and nos. 19—21; the lack of anomalies in nos. 19—21 (the hindmost precaudal vertebrae) may simply be a consequence of the fact that in the complete material we find only 1.248 vertebrae of these serial numbers; in the material as a whole we have to count about 2.000 vertebrae in order to find one anomalous vertebra.

Among the caudal vertebrae no anomalies were found in nos. 6 and 19 or nos. 29—33. The lack of anomalies within nos. 31—33 may simply be caused by the numerical inferiority (1.528 of vertebrae of these serial numbers. Judging from the general frequency of the anomalies, however, they should be able to appear in nos. 29 and 30. The fact that they do not occur here shows us that in the very hindmost vertebrae of the spinal column anomalies are at any rate rare.

For the rest the number of anomalous vertebrae shows a somewhat varying distribution in the spinal column. They are more frequent in the tail than in the body, the numbers amounting to 0.52 per mille in the caudal as against 0.42 per mille in the precaudal vertebrae. Among the precaudal vertebrae anomalies

Table 1. The distribution of anomalous vertebrae through the vertebral column.

	No. of vertebrae	Number of anomalous vert.	Total number of individuals with this vert.	Number of anom- alous vert. in ‰
Vert. prec.	1	3	6 734	0.45
	2	3	—	0.45
	3	3	—	0.45
	4	1	—	0.15
	5	4	—	0.59
	6	5	—	0.74
	7	3	—	0.45
	8	3	—	0.45
	9	1	—	0.15
	10	4	—	0.59
	11	5	—	0.75
	12	3	—	0.45
	13	2	—	0.30
	14	2	—	0.30
	15	0	—	0
	16	0	6 732	0
	17	4	6 590	0.61
	18	4	4 547	0.61
	19		1 138	0
	20		108	0
	21		2	0
Total ...		50	120 127	0.42
Vert. cand.	1	1	6 715	0.15
	2	4	—	0.60
	3	4	—	0.60
	4	2	—	0.30
	5	2	—	0.30
	6	0	—	0
	7	3	—	0.45
	8	2	—	0.30
	9	1	—	0.15
	10	5	—	0.74
	11	8	—	1.19
	12	9	—	1.34
	13	8	—	1.19
	14	5	—	0.74
	15	3	—	0.45
	16	3	—	0.45
	17	4	—	0.60
	18	2	—	0.30
	19	0	—	0
	20	2	—	0.30
	21	3	—	0.45
	22	2	—	0.30
	23	3	—	0.74
	24	5	—	1.19
	25	8	—	1.19
	26	8	—	1.19
	27	5	6 715	0.74
	28	2	6 708	0.30
	29	0	6 427	0
	30	0	4 614	0
	31	0	1 415	0
	32	0	112	0
	33	0	1	0
Total ...		104	200 582	0.52

are comparatively frequent in nos. 5 and 6, nos. 10 and 11, and nos. 17 and 18. In the tail the most numerous anomalies occur in nos. 2 and 3, nos. 10, 11, 12, 13 and 14, no. 17 and nos. 23, 24, 25, 26 and 27.

Ford & Bull¹⁾ have examined the problem of distribution of anomalous vertebrae in the spinal column of the herring and found that anomalous vertebrae will mostly appear in the parts of the vertebral column off which there is a backward change of position of the pectoral fins and a forward change of the vent during the development of the

B. Variations in numbers of vertebrae and keeled scales from one water to the other.

For each analysis within the different areas of water table 2 gives the results of the countings of vertebrae and keeled scales (K_2). The vertebrae are given as precaudal (prec. V.), caudal vertebrae (caud. V.) and in total number (Vert. S.) The maps figs. 5 and 6 show the total number of vertebrae and the number of keeled scales for each analysis. In the following we find a combination of numbers of vertebrae and keeled scales from the individual waters, the figures in brackets representing the numbers of individuals examined:

	prec. V.	caud. V.	Vert. S.	K_2
Skagerak + north. Kattegat.....	17.95 (1 801)	30.02 (1 801)	47.95 (1 807)	11.73 (1 548)
South. Kattegat	18.07 (443)	29.88 (443)	47.90 (450)	11.70 (326)
Isefjord	17.89 (303)	29.90 (304)	47.79 (305)	11.54 (278)
North. Belt Sea.....	17.83 (1 132)	29.92 (1 128)	47.75 (1 118)	11.66 (937)
South. Belt Sea	17.83 (500)	29.72 (496)	47.55 (506)	11.48 (404)
Limfjord	17.71 (2 456)	29.79 (2 453)	47.51 (2 461)	11.50 (1 522)
Mariager Fjord	17.71 (91)	29.37 (90)	47.12 (104)	
True Baltic	17.83 (214)	29.91 (215)	47.72 (213)	11.48 (213)

larvae. According to Lebour²⁾ there is only a quite insignificant change of position of the pectoral fins in sprat from about the 21. and 22. vertebra or in other words from off the 3. caudal vertebra, which means that this change of position takes place within a region showing particularly many anomalies in the sprat, viz. the 2. and 3. caudal vertebra with 0.60 per mille of anomalies. In the sprat the vent moves from the 19. to the 15. caudal vertebra, a region showing few anomalies. The hind edge of the dorsal fin, however, changes its position from the 15. to the 13. caudal vertebra within a region showing many anomalies, 0.45—1.19 per mille. On the other hand the change of the front edge of the dorsal fin from the 9. to the 4. caudal vertebra falls within a region of few anomalies. In the case of the sprat, therefore, the material at hand only to some extent allows us to combine the occurrence of anomalies in the vertebral column with changes of position of the vent and the unpaired fins during the development.

¹⁾ Ford, E. and Bull, H. O.: Abnormal Vertebrae in Herrings. Journ. Mar. Biol. Ass. Plymouth, XIV, 1926.

²⁾ Lebour, N. V.: The Larval and Post-Larval Stages of the Pilchard, Sprat and Herring from Plymouth District. Journ. Mar. Biol. Ass. Plymouth, XII, 1921.

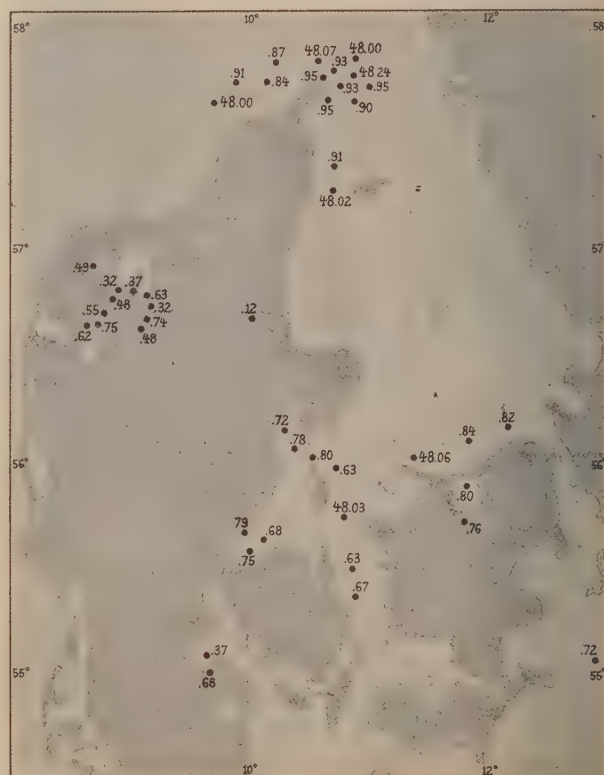


Fig. 5. Mean numbers of vertebrae (47 omitted) in analyses of sprat from Danish waters.

Table 2 A. Number of vertebrae praecaudales (V.P.), vertebrae caudales (V.C.), and total number of vertebrae (V.S.), together with the number of keeled scales (K_2) in analyses of sprat from the Skagerak and the northernmost Kattegat.

No. of analysis		2	6	7	15	16	20	21	33	34	43	44	45	49	50	51	53	56	58	59	To- tal	
V.P.	16	2	..	..	6	1	3	..	1	..	1	1	3	..	1	2	3	3	1	..	28	
	17	50	..	10	90	18	12	11	27	12	15	24	21	11	8	25	37	50	25	40	486	
	18	99	..	9	135	18	24	21	46	7	44	71	63	8	26	62	80	59	55	47	874	
	19	42	..	2	41	8	7	13	20	7	32	27	21	30	8	28	24	32	10	21	373	
	20	5	..	..	3	..	..	..	4	1	7	8	2	..	2	..	3	3	..	1	39	
	21	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	
n	199	..	21	275	45	46	45	98	27	99	131	110	49	45	117	147	147	91	109	1801		
M.	18.01	..	17.62	17.80	17.73	17.76	18.04	17.99	17.89	18.29	18.13	17.98	18.39	18.04	17.99	17.92	17.88	17.81	17.85	17.95		
σ	0.81	..	0.65	0.75	0.78	0.79	0.73	0.83	0.93	0.85	0.81	0.76	0.84	0.80	0.73	0.76	0.84	0.63	0.77	0.78		
σ_m	0.06	..	0.14	0.05	0.12	0.12	0.11	0.08	0.18	0.09	0.07	0.07	0.12	0.12	0.07	0.06	0.07	0.07	0.08	0.019		
V.C.	27	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	
	28	5	..	..	2	..	..	2	4	..	12	3	3	..	2	4	2	3	2	4	48	
	29	51	..	1	54	9	11	13	23	6	30	37	20	10	12	26	38	31	13	21	406	
	30	94	..	8	140	21	17	20	43	14	44	72	55	25	17	55	65	78	42	48	858	
	31	39	..	10	69	13	13	9	24	7	13	18	28	14	14	29	40	29	34	32	435	
	32	8	..	2	10	2	5	..	4	..	..	1	4	..	1	3	2	6	..	4	52	
n	199	..	21	275	45	46	44	98	27	99	131	110	49	46	117	147	147	91	109	1801		
M.	29.94	..	30.62	30.11	30.18	30.26	29.82	30.01	30.04	29.59	29.82	30.09	30.08	30.00	30.01	30.01	30.03	30.19	30.10	30.02		
σ	0.90	..	0.72	0.78	0.80	0.94	0.80	0.89	0.69	0.86	0.71	0.83	0.70	0.92	0.85	0.80	0.81	0.76	0.88	0.84		
σ_m	0.06	..	0.16	0.05	0.12	0.14	0.12	0.09	0.13	0.09	0.06	0.08	0.10	0.14	0.08	0.07	0.07	0.08	0.09	0.020		
V.S.	46	1	..	..	4	1	..	..	..	..	..	2	..	..	2	2	2	4	..	1	19	
	47	47	..	4	58	11	7	12	21	6	27	22	18	11	8	17	28	30	18	26	371	
	48	113	..	10	173	24	31	27	57	17	66	87	66	26	21	77	96	91	55	61	1098	
	49	37	..	5	39	9	8	5	19	4	13	20	26	12	14	21	21	21	18	20	312	
	50	1	..	2	1	..	..	..	1	..	..	..	..	..	..	..	..	1	..	1	7	
n	199	..	21	275	45	46	44	98	27	106	131	110	49	45	117	147	147	91	109	1807		
M.	47.95	..	48.24	47.91	47.91	48.02	47.84	48.00	47.93	47.87	47.95	48.07	48.02	48.04	48.00	47.93	47.90	48.00	47.95	47.95		
σ	0.68	..	0.87	0.63	0.73	0.57	0.60	0.67	0.61	0.60	0.62	0.63	0.69	0.83	0.63	0.62	0.48	0.63	0.71	0.66		
σ_m	0.05	..	0.19	0.04	0.11	0.08	0.09	0.07	0.12	0.06	0.05	0.06	0.10	0.12	0.06	0.05	0.04	0.07	0.07	0.016		
K ₂	9	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	2	
	10	3	1	..	2	1	1	2	..	4	1	..	..	..	2	3	7	5	3	4	2	41
	11	69	43	14	52	13	17	16	34	37	32	..	..	..	18	16	43	29	32	38	30	533
	12	102	49	41	86	24	26	24	51	56	59	..	..	..	26	15	51	28	25	53	59	775
	13	26	9	12	20	4	2	2	13	10	15	..	..	..	3	7	15	8	10	19	19	194
14	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	3	
n	200	102	67	161	42	46	44	98	107	107	..	..	49	42	117	70	70	115	111	1548		
M.	11.76	11.65	11.97	11.79	11.74	11.63	11.59	11.79	11.67	11.82	..	..	11.61	11.57	11.62	11.56	11.60	11.78	11.88	11.73		
σ	0.68	0.84	0.62	0.69	0.65	0.60	0.65	0.50	0.70	0.67	..	..	0.67	0.94	0.82	0.79	0.79	0.79	0.74	0.72		
σ_m	0.05	0.08	0.08	0.05	0.10	0.09	0.10	0.05	0.07	0.07	..	..	0.10	0.15	0.08	0.10	0.09	0.07	0.07	0.018		

Starting with the total number of vertebrae (Vert. S.) we find that the values are highest, 47.95, in the Skagerak and the northern Kattegat. The map (fig. 5) shows us that the number of vertebrae does not differ in the Skagerak and the northern Kattegat.

From these waters there is a decrease of the number of vertebrae partly southwards through the Danish waters, partly into our fjords: in the southern Belt Sea the number of vertebrae falls to 47.55, in the Limfjord to 47.51, in the Mariager Fjord even to

Table 2 B. Number of vertebrae praecaudales (V. P.), vertebrae caudales (V. C.), and total number of vertebrae (V. S.), together with the number of keeled scales (K_2) in analyses of sprat from the Limfjord.

No. of analysis	1	4	8	9	10	17	18	19	23	24	25	26	29	32	37	41	42	47	57	Total	
V.P.	15	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	2	
	16	7	1	2	8	7	5	2	3	5	1	2	5	12	5	4	2	3	2	4	80
	17	35	45	42	37	59	58	22	52	18	17	20	16	86	77	62	89	49	33	41	858
	18	66	77	60	62	65	88	22	55	38	38	43	45	49	91	106	93	94	68	57	1 217
	19	24	17	9	9	12	20	5	6	9	6	10	4	8	33	42	18	35	3	8	278
	20	3	..	3	..	..	3	..	..	..	..	..	1	..	2	2	2	5	..	..	21
n	135	140	116	116	144	175	51	116	70	62	75	71	155	208	216	204	186	106	110	2 456	
M.	17.87	17.79	17.73	17.62	17.56	17.74	17.59	17.55	17.73	17.79	17.81	17.72	17.34	17.76	17.80	17.65	17.95	17.68	17.63	17.71	
σ	0.83	0.65	0.74	0.73	0.74	0.79	0.72	0.64	0.77	0.48	0.69	0.73	0.70	0.78	0.76	0.70	0.79	0.56	0.62	0.75	
σ_m	0.07	0.05	0.07	0.07	0.06	0.06	0.10	0.06	0.09	0.06	0.08	0.09	0.06	0.05	0.05	0.05	0.06	0.06	0.06	0.015	
V.C.	27	..	1	..	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	3	
	28	10	2	2	4	7	10	4	6	6	2	2	3	5	14	13	4	11	3	7	115
	29	34	41	30	27	48	45	14	35	22	17	26	28	22	60	76	66	78	29	41	739
	30	57	71	56	51	62	80	23	54	33	35	37	32	76	106	105	94	76	66	42	1 156
	31	30	28	26	31	27	37	8	20	8	7	10	6	52	26	19	37	19	7	19	417
	32	4	1	3	2	..	3	..	1	1	..	..	1	1	1	2	2	..	..	1	23
n	135	144	117	115	144	175	50	116	70	61	75	70	156	207	216	203	184	105	110	2 453	
M.	29.88	29.88	29.98	30.00	29.76	29.87	29.66	29.78	29.66	29.77	29.73	29.63	30.14	29.71	29.62	29.83	29.56	29.73	29.69	29.79	
σ	0.94	0.76	0.81	0.84	0.81	0.87	0.91	0.82	0.84	0.69	0.72	0.76	0.78	0.79	0.79	0.76	0.76	0.62	0.79	0.82	
σ_m	0.08	0.06	0.07	0.08	0.07	0.07	0.13	0.08	0.10	0.09	0.08	0.09	0.06	0.05	0.05	0.06	0.06	0.06	0.08	0.016	
V.S.	45	..	..	..	1	1	..	1	..	..	..	1	..	..	..	1	..	..	..	5	
	46	5	7	3	7	9	12	5	8	6	7	4	10	12	13	11	11	12	12	9	163
	47	40	48	35	36	83	55	26	62	37	22	29	32	65	90	94	95	81	39	61	1 030
	48	76	71	65	61	46	96	17	39	23	27	35	27	69	100	98	88	86	51	36	1 111
	49	13	14	12	10	6	12	1	5	5	7	8	3	9	6	12	10	8	4	4	149
	50	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	2
51	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1	
n	135	140	115	115	145	175	50	114	71	63	77	73	155	209	216	204	188	106	110	2 461	
M.	47.74	47.66	47.75	47.63	47.32	47.62	47.24	47.36	47.38	47.54	47.58	47.37	47.48	47.47	47.50	47.48	47.49	47.44	47.32	47.51	
σ	0.71	0.72	0.67	0.76	0.69	0.71	0.74	0.68	0.69	0.83	0.80	0.89	0.72	0.66	0.70	0.67	0.71	0.74	0.54	0.73	
σ_m	0.06	0.06	0.06	0.07	0.06	0.05	0.10	0.06	0.08	0.10	0.09	0.10	0.06	0.05	0.05	0.05	0.05	0.07	0.05	0.015	
K ₂	10	6	7	5	5	..	10	3	..	3	..	5	7	1	7	3	8	6	8	4	88
	11	41	71	45	44	..	102	23	..	26	..	26	22	10	57	24	38	42	54	45	670
	12	41	55	63	58	..	105	24	..	16	..	18	20	10	39	33	50	44	44	60	680
	13	3	13	7	9	..	9	3	..	3	..	4	1	..	5	5	8	3	7	3	83
14	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	1	
n	91	146	120	116	..	226	53	..	48	..	53	50	21	108	66	104	95	113	112	1 522	
M.	11.45	11.51	11.60	11.61	..	11.50	11.51	..	11.40	..	11.40	11.30	11.43	11.39	11.65	11.56	11.46	11.44	11.55	11.50	
σ	0.67	0.78	0.66	0.69	..	0.65	0.69	..	0.65	..	0.76	0.73	0.60	0.68	0.75	0.74	0.66	0.72	0.55	0.69	
σ_m	0.07	0.06	0.06	0.06	..	0.04	0.09	..	0.09	..	0.10	0.10	0.13	0.07	0.09	0.07	0.07	0.07	0.05	0.018	

47.12. But in the Baltic there is another rise of the number: at Kriegers Flak in the western part of the true Baltic it is as high as 47.72 and in the Stockholm Skärgård far back in the true Baltic it is even higher (48.16) than in the Skagerak and the northern Kattegat. By way of comparison may be mentioned that

Chr. Hessel¹⁾ found the following mean figures for the total numbers of vertebrae in sprat from various parts of the Baltic:

¹⁾ Hessel, Chr.: Sprat and Sprat-Fishery on the Baltic Coast of Sweden. Medd. Kungl. Lantbruksstyrelsen. No. 262. 1927.

Table 2C. Number of vertebrae praecaudales (V.P.), vertebrae caudales (V.C.), and total number of vertebrae (V.S.), together with the number of keeled scales (K_2) in analyses of sprat from the southern Kattegat, the Isefjord, and the northern Belt Sea.

No. of analysis	South. Kattegat				The Isefjord			Northern Belt Sea										Total
	30	36	40	Total	11	35	Total	3	5	12	13	14	22	31	38	39	54	
V.P.	16	1	..	1	2	2	4	1	2	..	3	6	..	1	3	3	2	21
	17	23	23	39	85	75	14	89	31	34	16	47	85	23	21	17	29	351
	18	18	68	104	255	117	39	156	40	44	31	82	109	52	37	30	75	573
	19	29	19	37	85	30	15	45	11	21	6	17	30	12	13	11	32	175
	20	5	2	8	15	1	8	9	3	2	1	..	3	1	..	..	2	12
	21	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..
n	141	112	190	443	225	78	303	86	103	54	149	233	88	72	61	141	145	1 132
M.	18.10	18.00	18.08	18.07	17.79	18.18	17.89	17.81	17.87	17.85	17.76	17.74	17.90	17.86	17.80	18.01	17.79	17.83
σ	0.73	0.67	0.79	0.74	0.69	0.92	0.78	0.80	0.82	0.68	0.67	0.76	0.66	0.71	0.78	0.76	0.71	0.74
σ_m	0.06	0.06	0.06	0.035	0.05	0.11	0.045	0.09	0.08	0.09	0.05	0.05	0.07	0.08	0.10	0.06	0.06	0.022
V.C.	27	..	..	1	1	..	..	..	..	1	..	..	..	..	..	..	..	1
	28	5	6	12	23	4	10	14	5	10	3	5	7	3	2	..	5	43
	29	32	24	48	104	52	25	77	15	31	10	39	50	14	19	19	47	279
	30	71	63	105	239	109	32	141	43	40	31	68	107	42	41	32	74	548
	31	30	17	23	70	58	10	68	18	19	11	34	61	28	10	11	12	236
	32	3	2	1	6	3	1	4	3	3	..	..	8	..	..	..	2	20
	33	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	1
n	141	112	190	443	226	78	304	84	103	56	146	233	88	72	62	140	144	1 128
M.	29.96	29.87	29.74	29.88	30.02	29.58	29.90	29.99	29.75	29.86	29.90	30.06	30.13	29.83	29.87	29.71	29.99	29.92
σ	0.81	0.65	0.79	0.76	0.78	0.91	0.84	0.88	0.86	0.85	0.79	0.85	0.84	0.68	0.68	0.73	0.82	0.83
σ_m	0.07	0.06	0.06	0.036	0.05	0.10	0.048	0.10	0.08	0.11	0.07	0.06	0.09	0.08	0.09	0.03	0.07	0.025
V.S.	46	..	..	4	4	1	3	4	3	6	1	5	3	..	3	3	6	32
	47	23	37	51	111	75	22	97	22	34	16	56	73	14	25	18	45	344
	48	89	61	114	264	118	46	164	48	56	31	73	124	58	36	36	73	618
	49	29	17	21	67	30	9	39	11	6	6	12	26	15	8	4	14	117
	50	1	1	2	4	1	..	1	..	1	..	..	3	1	..	..	2	7
	51	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
n	142	116	192	450	225	80	305	84	103	54	146	229	88	72	61	140	141	1 118
M.	48.06	47.84	47.82	47.90	47.80	47.76	47.79	47.80	47.63	47.78	47.63	47.79	48.03	47.68	47.67	47.92	47.79	47.75
σ	0.63	0.69	0.68	0.68	0.68	0.70	0.68	0.70	0.72	0.65	0.86	0.71	0.61	0.72	0.67	0.76	0.64	0.70
σ_m	0.05	0.06	0.05	0.032	0.05	0.08	0.039	0.05	0.07	0.09	0.07	0.05	0.06	0.09	0.09	0.06	0.05	0.021
K_2	10	5	4	..	9	8	2	10	3	1	4	1	6	4	2	2	4	29
	11	49	32	52	133	91	28	119	34	37	53	36	60	36	21	17	37	359
	12	57	44	37	138	103	34	137	42	51	56	58	84	41	28	19	35	450
	13	17	6	17	40	10	2	12	7	11	10	18	27	8	3	5	6	99
	14	..	..	5	5	..	..	..	..	..	..	..	..	..	..	..	..	..
	15	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..
n	128	86	112	326	212	66	278	86	100	123	113	177	89	54	43	82	70	937
M.	11.67	11.60	11.80	11.70	11.54	11.55	11.54	11.62	11.72	11.59	11.82	11.75	11.60	11.59	11.63	11.52	11.70	11.66
σ	0.75	0.69	0.73	0.80	0.65	0.60	0.64	0.59	0.45	0.68	0.70	0.75	0.71	0.66	0.75	0.71	0.65	0.71
σ_m	0.07	0.07	0.07	0.044	0.04	0.07	0.038	0.06	0.05	0.06	0.07	0.06	0.08	0.09	0.11	0.08	0.08	0.023

Karlskrona (Blekinge) 48.27 (50 ind.) Värskär (Småland) 48.00 (46 ind.)
 Östergarn (Gotland) 48.00 (51 ind.) Oxelö Sund (Östergötland) 48.10 (50 ind.)

Table 2D. Number of vertebrae praecaudales (V.P.), vertebrae caudales (V.C.), and total number of vertebrae (V.S.), together with the number of keeled scales (K_2) in analyses of sprat from the southern Belt Sea, Mariager Fjord, and the true Baltic.

No. of analysis	Southern Belt Sea					Mariager Fjord	The true Baltic
	28	46	48	55	Total	27	52
V.P. {	16	2	1	..	3	6	6
	17	26	40	21	52	139	63
	18	58	83	80	69	290	111
	19	16	11	14	22	63	30
	20	..	2	..	..	2	4
	21	..	..	..	..	..	..
n	102	137	115	146	500	91	214
M.	17.86	17.80	17.94	17.75	17.83	17.71	17.83
σ	0.69	0.65	0.55	0.73	0.66	0.69	0.77
σ_m	0.07	0.06	0.05	0.06	0.030	0.07	0.05
V.C. {	27	..	..	..	..	..	2
	28	6	9	7	7	29	7
	29	28	56	50	32	166	59
	30	46	54	49	72	221	92
	31	21	17	7	29	74	46
	32	1	..	1	4	6	8
n	102	136	114	144	496	90	215
M.	29.83	29.58	29.52	29.94	29.72	29.37	29.91
σ	0.82	0.79	0.74	0.86	0.83	0.70	0.94
σ_m	0.08	0.07	0.07	0.07	0.037	0.07	0.06
V.S. {	46	8	13	7	5	33	12
	47	31	68	54	47	200	62
	48	52	58	50	78	238	112
	49	12	4	4	13	33	27
	50	1	..	..	..	1	..
	51	..	..	1	..	1	..
n	104	143	116	143	506	104	213
M.	47.68	47.37	47.47	47.69	47.55	47.12	47.72
σ	0.81	0.69	0.74	0.68	0.74	0.71	0.75
σ_m	0.08	0.06	0.07	0.06	0.033	0.07	0.05
K_2 {	10	3	8	12	1	24	15
	11	54	53	52	3	189	92
	12	41	39	47	36	163	94
	13	8	10	7	3	28	12
n	106	110	118	70	404	..	213
M.	11.51	11.46	11.42	11.59	11.48	..	11.48
σ	0.68	0.76	0.75	0.60	0.71	..	0.71
σ_m	0.07	0.07	0.07	0.07	0.036	..	0.05

There are no Danish analyses from the western Baltic, but 68 sprat from the Kiel Bay were examined by Fr. Heincke¹⁾, who found their mean number

¹⁾ Fr. Heincke: Naturgeschichte des Herings. I und II. Abh. d. deutschen Seefischerei Vereins. 1898.

of vertebrae to be 47.5 or nearly the same as in the southern Belt Sea.

There is some difference between the variation of the number of vertebrae and that of the number of keeled scales. In the Skagerak and the northern

Kattegat the mean figure for K_2 is 11.73. From these waters inwards there is a gradual fall of the figure. In the southern Kattegat it is 11.70 in the northern Belt Sea 11.66. In the southern Belt Sea and the western part of the true Baltic it is much lower, being only 11.48. Also in our fjords the numbers of keeled scales are comparatively low, in the Isefjord for instance 11.54, in the Limfjord 11.50. In the western Baltic (Kiel Bay) Fr. Heincke (l. c.) found the low mean figure 11.3, but the sample from this locality comprises only 159 individuals, and so it is possible that the number of K_2 in this water does not in fact deviate very much from the mean number of the sprat of the southern Belt Sea.

While the vertebrae of the sprat rose in number from the southern Danish waters and south- and northwards into the Baltic, there is no such rise in the number of K_2 . Chr. Hessle (l. c.) gives the following values for K_2 from different places of the east coast of Sweden:

Karlshamn (Blekinge).....	11.53 (45 ind.)
Karlskrona (Blekinge)	11.48 (50 ind.)
Östergarn (Gotland)	11.54 (50 ind.)
Värskär (Småland)	11.59 (49 ind.)
Oxelö Sund (Östergötland)	11.33 (51 ind.)

In other words the mean numbers of keeled scales of the sprat in these waters are low and of fairly the same size as in the sprat in the southern Danish waters. The low figure found in the sample from Östergötland seems to indicate a further fall in a northerly direction along the east coast of Sweden, so that the lowest value will occur next to the inner limit of the sprat in the Baltic.

It is well-known from other fishes that the different numerical characters do not vary in the same way towards our inner waters. In the following table the mean numbers of vertebrae and anal or dorsal fin rays in various Danish waters are given for plaice,

		North Sea Skagerak	South. Belt Sea West. Baltic	True Baltic
Plaice ...	{ Vert. S.	43.0	42.3	42.9
	{ anal fin rays ...	54.0	51.0	52.1
Dab	{ Vert. S.	40.3	40.2	40.3
	{ anal fin rays ...	57.0	54.6	54.2
Cod	{ Vert. S.	52.1	51.6	52.0
	{ 2. dors. fin rays.	19.0	18.4	17.5

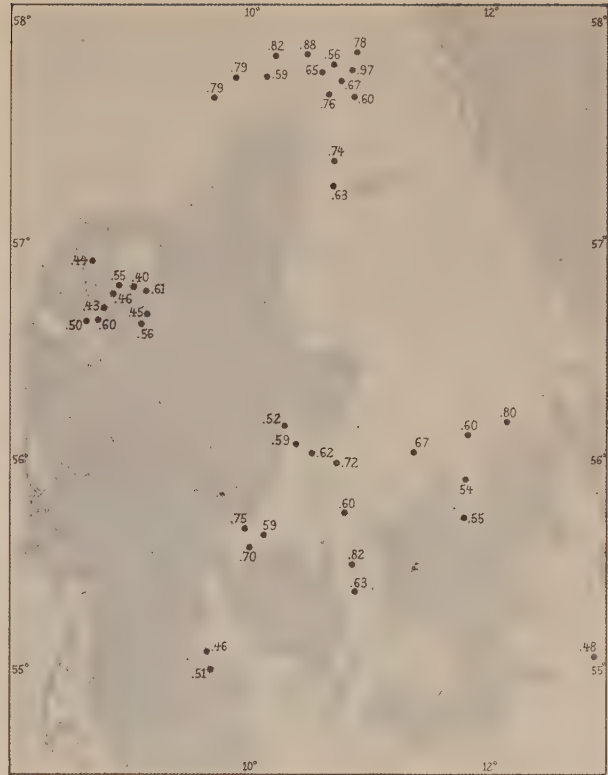


Fig. 6. Mean numbers of keeled scales, K^2 , (11 omitted) in analyses of sprat from Danish waters.

dab and cod; the table partially bases on figures from Aage J. C. Jensen¹⁾ and Johs. Schmidt²⁾:

It appears from this that the numbers of vertebrae in plaice and cod fall in our inner waters, but rise again in the Baltic to nearly the same height as in the North Sea and the Skagerak. These changes parallel those of the sprat. With regard to the fin rays matters are not so simple: in dab and cod they fall in number, as do the keeled scales of the sprat, through our waters and far into the Baltic, but in the plaice the number of anal fin rays shows some rise from our southern waters to the Baltic. Though both keeled scales and the rays of anal and dorsal fins like the number of vertebrae belong to the numerical characters that are co-ordinated with the longitudinal axis of the body, they vary in a somewhat different way; in other words they are not affected in the same

¹⁾ Aage J. C. Jensen: The Races of Dab in the Danish Waters. Rep. Dan. Biol. Stat. XLII, 1938.

²⁾ Johs. Schmidt: The Atlantic Cod (*Gadus callarias* L.) and Local Races of the Same. Comptes-Rendus des Travaux du Laboratoire Carlsberg. Vol. 18 nr. 6. 1930.

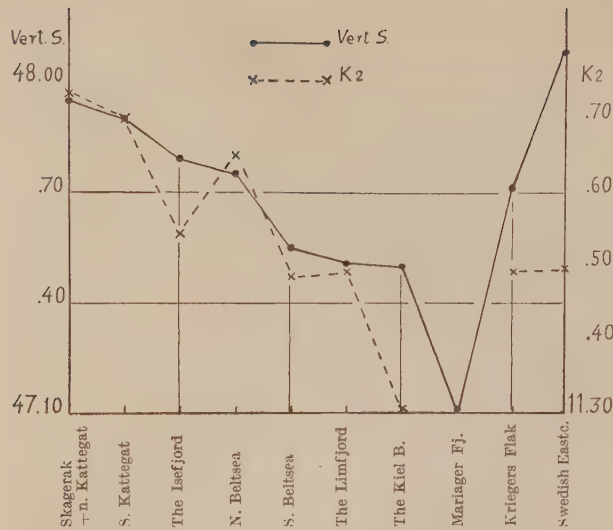


Fig. 7. Mean figures for vertebrae and keeled scales, K_2 , in the different areas of water from the Skagerak to the Baltic.

manner by the conditions determining the variation of these characters.

An examination of the variation of these characters in a larger number of species in the waters from the North Sea to the Baltic is no doubt necessary in order to find out the causes of the changes of character from one water to the other.

A comparison of the variation in the mean numbers of vertebrae (Vert. S.) and of keeled scales (K_2) through the Danish waters and into the eastern Baltic is found in Fig. 7. It is seen that the lower mean numbers of vertebrae and keeled scales in our inner waters and in the fjords are reached through a gradual fall from north to south, so that the stock of the southern Kattegat and the northern part of the Belt Sea with regard to these characters take up an intermediary position between the sprat of the Skagerak and the northern Kattegat on one side and those of the southern Belt Sea and the Limfjord on the other. This state of things complicates the division of the sprat populations into races, and furthermore such a division is rendered difficult by the fact that our knowledge of the situation of the spawning areas of the sprat throughout the area is rather limited. A look at the map figure 1 will show that as regards catching areas we have 3 well-defined areas in our waters: i. a northern area in the Skagerak and the northern Kattegat, ii. a southern area in the southern Kattegat and the Belt Sea and iii. an area including the central and western part of the Limfjord. From observations of eggs we know that the

sprat spawns in the Limfjord. In view of the fact that sprat are hardly found and sprat eggs are extremely rare in the narrow eastern part of the Limfjord and that the sprat fishery in the adjacent part of the Kattegat is of inferior importance there can be no doubt that the sprat of the Limfjord make up a separate population without connexion with our other sprat populations.

From the populations of the Skagerak + the northern Kattegat and of the central Kattegat the Limfjord sprat differs distinctly by its numbers of vertebrae and keeled scales:

	Skagerak + north. Kattegat	South. Kattegat	Limfjord
Vert. S.	47.95 ± 0.016	47.90 ± 0.032	47.51 ± 0.015
Vert. prec. . .	17.95 ± 0.019	18.07 ± 0.035	17.71 ± 0.015
Vert. caud. . .	30.02 ± 0.013	29.88 ± 0.036	29.79 ± 0.016
K_2	11.73 ± 0.013	11.70 ± 0.044	11.50 ± 0.018

If we add 3 times the mean error to the mean figures of the Limfjord and subtract 3 times the mean error from the figures of the Skagerak and the Kattegat, we get the following lowest possible mean values of Vert. S. and K_2 for the Skagerak-Kattegat and highest possible mean values for the Limfjord:

	Skagerak + north. Kattegat	South. Kattegat	Limfjord
Vert. S.	47.90	47.81	47.56
K_2	11.68	11.63	11.55

In other words there is a distinct difference between the mean figures of the Limfjord and of the other two areas; moreover the spawning places of the sprat of the three areas are situated far from each other, and so the sprat of the Limfjord may well be considered to belong to another race than the sprat of the Skagerak and the Kattegat.

As regards numbers of vertebrae and keeled scales there is, however, hardly any difference between the Limfjord sprat and the sprat of the southern Belt Sea.

	South. Belt Sea	Limfjord
Vert. S.	47.55 ± 0.033	47.51 ± 0.015
Vert. prec.	17.83 ± 0.030	17.71 ± 0.015
Vert. caud.	29.72 ± 0.037	29.79 ± 0.016
K_2	11.48 ± 0.036	11.50 ± 0.018

The difference between the mean figures of the two areas is so small, that it shows no difference of race. But in view of the facts that the spawning areas of the two populations are situated far from each other and that they are further separated from each other by waters (the southern Kattegat and the

northern Belt Sea) populated by stocks with numbers of vertebrae and keeled scales that differ distinctly from the figures of the sprat in the Limfjord and the southern Belt Sea, it would be absurd to believe that the sprat populations of these two waters belong to the same race.

With its low number of vertebrae, 47.12 ± 0.07 , the sprat of the Mariager Fjord must be considered a separate race. Here the number of vertebrae is even considerably lower than in the neighbouring sprat populations, the Limfjord with 47.51 ± 0.015 and the southern Kattegat with 47.90 ± 0.032 . Here we undoubtedly have a special fjord-race characterised by a very low number of vertebrae. The sprat of the Mariager Fjord is stated to be of comparatively small size, somewhat smaller than the Limfjord sprat. It seems that this special race of fjord sprat is characterised not only by a particularly low number of vertebrae but also by a comparatively smaller size.

It is a more dubious question how the sprat populations of the southern Kattegat, the Isefjord and the northern Belt Sea should be defined. In numbers of vertebrae and keeled scales the sprat of the southern Kattegat correspond closely to the sprat race of the northern Kattegat and the Kattegat:

	North. Kattegat + Skagerak	South. Kattegat
Vert. S.	47.95 ± 0.016	47.90 ± 0.032
K ₂	11.73 ± 0.018	11.70 ± 0.044

Here the difference in mean figures is so small that no actual difference between the two populations can be established. On the other hand there is hardly much connexion between them: they are separated from each other by a large area of the central Kattegat, in which there is hardly any fishing of sprat; furthermore Hans Höglund¹⁾ has pointed out that the spawning area of the sprat of the northern Kattegat does not reach farther southwards than halfway between Læsø and Anholt; so there is a comparatively large area of the southern and central Kattegat in which the sprat hardly spawns. Numerous findings through the years during fishing experiments with the Hensen net show that there is another spawning area of the sprat in the southwestern Kattegat through the Belt Sea and the western Baltic into the true Baltic.

¹⁾ Hans Höglund: Über die horizontale und vertikale Verteilung der Eier und Larven des Spratts (*Clupea sprattus* L.) im Skagerak-Kattegatgebiet. Svenska Hydr.-Biol. Kom. Skr. N. S. Biol. II, 3. 1938.

The mean figures for vertebrae and keeled scales of the sprat in the southern Kattegat and the northern part of the Belt Sea are as follows:

	South. Kattegat	North. Belt Sea
Vert. S.	47.90 ± 0.032	47.75 ± 0.021
K ₂	11.70 ± 0.044	11.66 ± 0.023

There is a difference here, but the mean error shows that it is not very important.

A comparison between the northern and the southern Belt shows a somewhat clearer difference:

	North. Belt Sea	South. Belt Sea
Vert. S.	47.75 ± 0.021	47.55 ± 0.033
K ₂	11.66 ± 0.023	11.48 ± 0.036

In this case the difference is much greater than 3 times the mean error, and so we are justified in concluding that a real difference exists between the populations of these two waters as regards vertebrae and keeled scales.

In accordance with the facts given above we may then take it that the following races of sprat are found in the Danish waters:

- the Skagen + northern Kattegat race
- the Limfjord race
- the fjord race
- the Baltic race
- the southern Kattegat + northern Belt Sea race
- the southern Belt Sea + western Baltic race

The two last-mentioned races are not so well distinguished from each other as from the other races or these races *inter se*, and no difference between their spawning areas has been established. So it is just possible that they should either be considered one race or that later investigations will show that they should be divided into several races.

Within several species of fish it has turned out that the mean numbers of keeled scales, fin rays and vertebrae may show some variation from one year-class to the other. Such variations have also been found in the sprat: A. Molander, 1940 (l. c.) demonstrated that the mean numbers of vertebrae in sprat from certain fjords of the west coast of Sweden are subject to some variation from year to year, from about 47.80 to about 48.05, and that the variations are nearly identical in the different fjords; he is of opinion that the variations in the number of vertebrae are due to a more or less extensive immigration from without of sprat of the sea-type, which have a

somewhat higher number of vertebrae than the fjord-type.

For the Danish material from the Skagerak + the northern Kattegat, the northern Belt Sea, and the Limfjord, i. e. the 3 areas from which the most extensive material exists, I have made a comparison between the results of analysis from the individual years or rather fishing seasons, the fishery starting in autumn and ending in spring:

	Vert S.			K ₂		
	Skagerak + north. Kattegat	Northern Belt Sea	Limfjord	Skagerak + north. Kattegat	Northern Belt Sea	Limfjord
1939/40	47.95	47.72	47.70	11.71	11.77	11.48
1940/41	48.02	47.76	47.57	11.83	11.72	11.61
1941/42	47.93	..	47.41	11.61	..	11.51
1942/43	..	48.03	47.48	..	11.60	11.37
1943/44	47.97	47.68	47.48	11.73	11.59	11.41
1944/45	..	47.80	47.49	..	11.58	11.61
1945/46	48.00	..	47.49	11.82	..	11.46
1946/47	48.02	..	47.44	11.60	..	11.44
1947/48	47.94	47.79	47.32	11.65	11.70	11.55
1948/49	47.95	..	..	11.88	..	..
highest difference.	0.09	0.35	0.38	0.28	0.19	0.24
highest difference between ind. analyses of more than 50 ind.	0.13	0.40	0.43	0.32	0.30	0.26

It appears from these figures that there may be some difference from year to year both in numbers of vertebrae and in numbers of keeled scales: in the Limfjord the difference between the highest and

the lowest number of vertebrae is 0.38; the greatest difference between the highest and the lowest number of keeled scales, 0.28, is found in the Skagerak + the northern Kattegat. But the material shows no correspondence between the different waters in the variations from year to year, for high mean figures in one area are not generally accompanied by high mean figures in the other areas. This circumstance favours the opinion advanced above that there is no particular connexion between the populations of these 3 areas. In other words there is hardly any reason to believe that the variations from year to year are due to a varying extent of an exchange of sprat between the different waters; if anything, it must be supposed that the variations are due to the varied influence of the conditions on the numerical characters.

If we look at the vertebrae alone, we find a conspicuous difference between the 3 areas in the fact that the fluctuations from year to year in the mean figure are much smaller in the Skagerak + the northern Kattegat (maximum difference 0.09) than in the northern Belt Sea and the Limfjord (maximum difference 0.35 and 0.38, respectively). This is no doubt connected with the fact that the fluctuations of conditions are of smaller extent in the larger open waters than in the fjords and belts.

In the case of the keeled scales the annual deviations from the mean are considerable greater than for the vertebrae, and they are of approximately the same size-border in all 3 areas.

Synopsis.

The sprat of the Danish waters can be divided into several populations, each of which belongs to a more or less limited area, and which hardly show any particular degree of intermingling. These various areas are separated from each other by intermediary areas where no fishery goes on or where it is at any rate of quite inferior importance, and in which the sprat do not spawn since no or only very few eggs have been found. In accordance with these facts each area has its own race (or perhaps its own races) of sprat.

In the Danish waters there are three such main areas with sprat:

1. An area including the eastern Skagerak and the northern Kattegat from off Hirtshals to the Swedish coast and southwards in the Kattegat to a position between Læsø and Anholt. Here lives a rather big

sprat, which, however, is comparatively lean; the mean size is 11.4 cm, the mean weight 10.7 g. In connexion with the fact that this sprat is rather lean the coefficient of nutrition is comparatively low, only 0.72. Accordingly, the market value of the sprat is rather low, in 1947 31 øre per kg. In a racial respect this sprat is characterised by a high number of vertebrae (47.95 ± 0.016) and a high number of keeled scales ($K_2 = 11.73 \pm 0.018$) and further by a very low number of anomalous vertebrae, only 0.2 per cent. of the individuals showing anomalies of vertebrae.

2. An area including the central and western part of the Limfjord. The sprat of this area is but small, the mean size being 9.1 cm, the mean weight 7.2 g. This sprat is not so lean as that of the first area,

and so its coefficient of nutrition is somewhat higher, 0.94; also its market value is higher, being 45 øre per kg in 1947. Racially this sprat is characterised by a low number of vertebrae (47.51 ± 0.015) and a low number of keeled scales ($K_2 = 11.50 \pm 0.018$). The number of anomalies in the vertebral column is higher than in the sprat of the Skagen area, anomalies occurring in 1.5 per cent. of the individuals.

3. An area reaching from the southernmost part of the Kattegat through the belts into the western Baltic. The sprat of this area show the best state of nutrition and are therefore the most valuable sprat (47 øre per kg in 1947) of the Danish waters. The mean length is a little lower than in the Skagen area, being only 10.7 cm, but the mean weight 12.2 g is higher than in the Skagen area; also the coefficient of nutrition is high, 0.99, which is a little higher than in the Limfjord and considerably higher than in the Skagen area. In this area there are evidently several races, of which that of the southern Kattegat with comparatively high numbers of vertebrae (47.90 ± 0.032) and keeled scales ($K_2 = 11.70 \pm 0.044$) is rather like that of the Skagen sprat. In the southern Belt Sea the numbers of vertebrae (47.55 ± 0.033) and keeled scales (11.48 ± 0.036) are essentially lower (nearly the same as those of the Limfjord and slightly higher than those of the western Baltic). Anomalies in the vertebral column are rather frequent, occurring in 2.2 per cent. of the individuals examined.

4. In certain fjords of this country there are evidently local races of small sprat with low numbers of vertebrae. Such a race with a number of only 47.12 ± 0.07 vertebrae was established to occur in the Mariager Fjord. On account of their small quantity and size of the individuals these races are of no particular importance in our fishery.

5. In the true Baltic from Kriegers Flak eastwards the sprat occurs over a large area both along the Swedish coast and along the south coast of the Baltic. At any rate in some localities this sprat is comparatively big: an analysis of sprat from Kriegers Flak gave a mean size of 13.3 cm.

In a racial respect the sprat from this part of the Baltic is characterised by a high number of vertebrae and a low number of keeled scales. At Kriegers Flak the vertebrae amounted to 47.72 ± 0.05 , rising to 48.0 farther back in the Baltic. The number of

keeled scales at Kriegers Flak was 11.45 ± 0.05 , and farther back in the Baltic it is about 11.5—11.3.

The fact that the sprat of this country are thus to some extent divided into populations and races, each of which belongs to its special water, is of importance for the question of regulating the fishery with a view to protecting the stock of sprat because such regulations will prove useful to the water within which they are enacted. Protective measures in the Limfjord for instance will be of advantage to the fishery of this very water because the sprat will not immigrate from here to other waters no more than the sprat of other waters will immigrate into the Limfjord. For the same reasons a too intense sprat fishery in the Skagerak and the northern Kattegat will primarily ruin the sprat population of these waters, but will hardly affect the sprat population farther southwards or in the Limfjord; it should be remembered, however, that the sprat population in the open water of the Skagerak and the northern Kattegat to some extent is connected with the sprat at and in the Skärgård of Sweden.

For its size the sprat has a comparatively rapid growth, and the fishery therefore depends on few (1 or 2) age groups, more particularly 1- or 2-years-old sprat, older fish playing an inferior part in the catches. In many cases the 1-year-old fish constitute the great majority of the catches landed. I have previously pointed out (1948) that it would be a rational procedure to protect the barely 1-year-old sprat, which are now caught during the winter season, for another year because these small sprat, which are mainly sold for industrial purposes, are of inferior market value.

The sprat spawns in May—June, and during this time it is of inferior market value; so it is obvious that a close season from May and well into the summer would be expedient because it will partly ensure the propagation of the sprat, partly prevent the catching of the less valuable, mature sprat, which are thus spared for the fishery of a later season when it shows a better state of nutrition.

In view of the fact that in the Skagerak and the northern Kattegat, in the western Baltic and the true Baltic we have populations of sprat in common with our neighbouring countries it is desirable that regulations for the protection of the sprat should be enacted by international agreement.

List of analyses of sprat from Danish waters.

No. of analysis	Locality	Depth m	Date	Gear
1	Hvalpsund, Limfjord	20	23-11-1939	Sprat seine
2	N. of Skagen	50	9-12-1939	—
3	Århus bay, N. Belt Sea	—	22-12-1939	Sprat trawl
4	Thisted br., Limfjord	11	30-12-1939	Sprat seine
5	Skadegrund, Århus bay	—	5- 1-1940	Sprat trawl
6	Off Skagen	—	25- 4-1940	—
7	9 M. N. b. E. of Grenen, Skagerak	60	15-10-1940	Trawl
8	Off Nymølle, Kås br., Limfjord	—	9-11-1940	Sprat seine
9	Off Jungetøre, Risgårde br., Limfjord	—	20-11-1940	Sprat trawl
10	1 M. N. of Rotholmene, Limfjord	—	19-11-1940	—
11	Isefjord	8	9-12-1940	Sprat seine
12	S. of Molshoved, Århus bay	—	16-12-1940	Sprat trawl
13	E. of Romsø, Great Belt	26	9- 1-1941	—
14	E. of Rosenvold Hage, Vejle Fjord	21	15- 1-1941	—
15	11 M. N. b. E. of Hirtshals, Skagerak	—	1- 2-1941	Trawl
16	8 M. N. of Læsø Rende L. V., N. Kattegat	—	27- 3-1941	Danish seine
17	Off Jegindø, Limfjord	2—4	16- 6-1941	Pound net
18	Thisted br., Limfjord	—	21-11-1941	Sprat trawl
19	Fur Sund, Limfjord	—	5-12-1941	—
20	Off Sæby, Læsø Rende, N. Kattegat	30	19-12-1941	—
21	15—20 M. NE. of Hirtshals, Skagerak	—	22- 2-1942	Trawl
22	Off Refsnæs, Great Belt	20	18-11-1942	Sprat trawl
23	Fur Sund, Limfjord	—	25-11-1942	—
24	Glyngøre, Limfjord	—	25-11-1942	—
25	Thisted br., Limfjord	—	5-12-1942	—
26	Off Glyngøre, Limfjord	—	9-12-1942	—
27	Mariager Fjord	—	4- 2-1943	—
28	Alssund, S. Belt Sea	12	18- 2-1943	Herring seine
29	Off Sillerslevøre, Sallingsund, Limfjord	—	23-11-1943	Sprat trawl
30	N. of Sjællands Odde, S. Kattegat	—	30-11-1943	—
31	Off Bogense, N. Belt Sea	14	14-12-1943	—
32	Thisted br., Limfjord	—	5- 1-1944	Sprat trawl
33	Off Hirtshals	—	28- 2-1944	Trawl
34	Off Skagen	—	26- 2-1944	—
35	Isefjord	9	24- 4-1944	—
36	N. of Hundested, S. Kattegat	—	27- 4-1944	—
37	Off Glyngøre, Limfjord	—	21-11-1944	Sprat trawl
38	N. of Sprogø, Great Belt	20—24	22-11-1944	Herring trawl
39	Århus bay	—	4-12-1944	Sprat trawl
40	N. of Gilleleje, S. Kattegat	24—30	4- 1-1945	Herring trawl
41	Hvalpsund, Limfjord	—	15- 2-1945	Sprat trawl
42	Thisted br., Limfjord	—	15- 1-1946	—
43	20 M. W $\frac{1}{2}$ N. of Grenen, Skagerak	70	26- 1-1946	Trawl
44	Off Skagen	—	13- 3-1946	—
45	Off Skagen	—	23- 3-1946	—
46	Åbenrå Fjord, S. Belt Sea	25	5-12-1946	Sprat trawl
47	Risgårde br., Limfjord	—	9-12-1946	—
48	Alssund, S. Belt Sea	12	24- 1-1947	—
49	15 M. NW. of Hirtshals	—	12- 2-1947	Herring trawl
50	18—20 M. NNE of Hirtshals	66	18- 3-1947	—
51	Off Hirtshals	—	25- 3-1947	—
52	Kriegers Flak, True Baltic	19	9- 5-1947	Herring seine
53	20 M. SSE. of Skagen	34	18-11-1947	Herring trawl
54	Off Bogense, N. Belt Sea	—	6-12-1947	—
55	Off Sønderborg	—	24-11-1947	Herring trawl
56	7 M. SSE. of Skagen	23	9-12-1947	Whiting trawl
57	Sallingsund, Limfjord	—	2- 3-1948	—
58	4 M. SE. of Skagen	47	7- 4-1948	Trawl
59	8 M. SSW. of Skagen	23	29-10-1948	Herring trawl

Contributions to the Biology of the Whiting (*Gadus
merlangus* L.) in the Danish Waters.

By

JØRGEN KNUDSEN

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I. Introduction.

THE whiting (*Gadus merlangus* L.) is common in the boreal part of the eastern Atlantic. In the north it advances as far as the Murman coast and Iceland, in the south it is found at Spain, and a closely related, perhaps identical form, *Gadus euxinus* v. Nordm. occurs in the Mediterranean and the Black Sea. In the Danish waters the whiting is widely distributed — though it decreases rapidly in frequency towards the Baltic where it is sometimes found as far eastwards as Gotland.

Up to now we have no collective survey of the biology of the whiting in the Danish waters, but papers on certain aspects of it have been published in the course of time. H. Blegvad, 1917¹⁾, examined the stomach contents of 125 whiting from Danish waters and found that the whiting mainly lives on crustaceans (gammarids, Crangon, mysids) and smaller fish, especially gobies and herring. E. M. Poulsen, 1932²⁾, discusses fluctuations in the amount of whiting of both larval and older age groups in the Danish waters between 1923 and 1935. H. Blegvad, 1945³⁾, deals with the whiting as part of the industrial fish. His paper i. a. contains a large number of length measurements of whiting from samples of industrial fish collected 1939—44.

In all essentials the present paper is based upon the material of whiting collected by the Biological Station during the fishing experiments with the eel seine carried out annually at a large number of stations in the Danish waters. The investigations covers the period 1927—39; from the following years there is no material because the war made it impossible to continue the fishing experiments in the Danish waters. In several respects, however, the present material is rather defective, mostly because the whiting to a much higher degree than the other

codfishes is a school-fish. Consequently, a reliable picture of for instance its vertical distribution or the fluctuations of the stock from year to year must be based on fishing experiments at a very large number of localities. Such experiments were not always carried out, especially not in the Baltic and the Skagerak. Another drawback is that investigations were made only during the period april to october; in fact, a comparatively comprehensive material exists only from the months of July, August and September. Nevertheless the material at hand has made it possible to throw a light on certain main features of the biology of the whiting, particularly in the Belt Sea and the Kattegat.

II. The importance of the whiting in the fishery.

As late as 20 years ago the whiting played a quite inferior part in the fishery. During the years after 1930, however, the landings of whiting have been rising in spite of great fluctuations from year to year. Part of the whiting landed is used for human food, but by far the greater part is used for industrial purposes, partly for fish-meal or fish-oil, partly as fodder at the trout pond farms. This fishing of fish for processing started about 1930, and notably during and after the war it rose to immense heights. Down to 1939 incl. "Fiskeriberetningen" gives the total amount of whiting landed, including both food fish and the amount used for industrial purposes. From 1940 the whiting used for human food is tabulated separately while the amount of fish for processing is given collectively without specification of the fishes contained in it. In spite of this it is possible to estimate the relative amount whiting in the industrial fish. H. Blegvad, 1945, states that in weight the whiting constitutes 14.2 per cent. of fish for processing from the inner waters (i. e. the area south of the eastern mouth of the Limfjord) and 52.9 per cent. of samples from the northern Kattegat and the Skagerak. H. Blegvad (l. c.) has further calculated that about $\frac{3}{4}$ of the fish for processing originate from the northern Kattegat, the Skagerak and the North Sea, $\frac{1}{4}$ coming from the inner waters,

¹⁾ H. Blegvad: On the Food of Fish in the Danish Waters within the Skaw. Rep. Dan. Biol. Stat. XXIV, 1917.

²⁾ E. M. Poulsen: Fluctuations in the Regional Distribution of Certain Fish-Stocks within the Transition Area during Recent Years (1923—35). Rapp. et Procès-Verb. CII. 1937.

³⁾ H. Blegvad: On the Waste Fish Fishery. Rep. Dan. Biol. Stat. XLVIII, 1945.

The following table gives the total yields of whiting from all Danish waters. The yields of the years 1940—48 were calculated on the basis of H. Blegvad's percentages of whiting in the fish for processing, and the figures further include the whiting given in "Fiskeriberetningen" as food fish.

Table 1. Yields in 1,000 tons of whiting from all Danish waters in the years 1925—48.

1925.....	0.19	1937.....	4.02
26.....	0.08	38.....	4.35
27.....	0.12	39.....	7.50
28.....	0.31	40.....	5.50
29.....	0.55	41.....	6.00
30.....	0.58	42.....	8.90
31.....	0.97	43.....	11.40
32.....	1.24	44.....	7.40
33.....	1.69	45.....	9.50
34.....	2.23	46.....	5.70
35.....	2.78	47.....	11.40
36.....	3.78	48.....	18.30

It will be seen from these figures that though there are considerable fluctuations in the yield from one year to another, a very considerable rise has taken place. The rise also appears from the graph figure 1, which is based on the figures given above, and from which it further emerges that there is a constant rise in the yield during the period 1925—38 without great fluctuations from year to year. The rise continues during the years 1938—48 though with great fluctuations in the yield from year to year—from 5.50 in 1940 to no less than 18.30 in 1948.

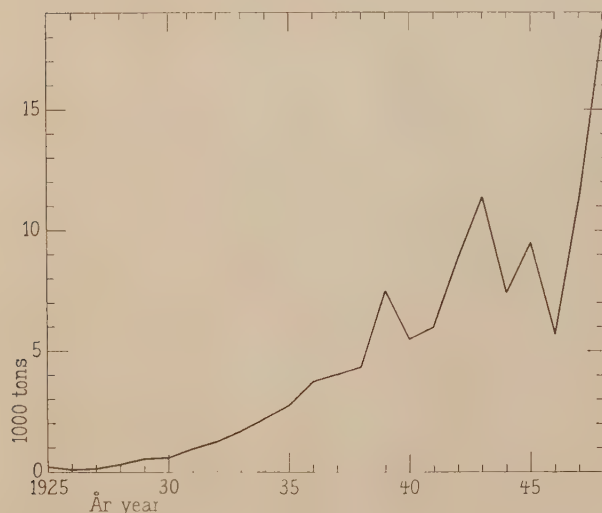


Fig. 1. The yield of the Danish whiting fishery in all Danish waters from 1925 to 1945. (From "Fiskeri-Beretningen").

III. The distribution of the larvae of the whiting.

The whiting hardly spawns in the Danish waters inside the Skagerak. The principal spawning places are found in the southern North Sea at depths of 20—60 m. Spawning places are also found in the northern North Sea and the Skagerak, especially along the south coast of Norway, in the Oslo Fjord and off the coast of Bohuslän. Eggs of whiting were found only occasionally in the southern and central part of the Kattegat. But already as tiny fry it immigrates into our inner waters, at any rate in certain years. E. M. Poulsen, 1937, brings a survey of the amount of larval whiting caught in the ring trawl in the Danish waters between 1923 and 1934. During this period there is only one year, 1923, in which a large number of larval whiting occurred in the inner Danish waters. In all the other years the numbers of larvae were quite insignificant. This is also true of the period 1935—39, during which extremely few larvae were taken. In two years, 1936 and 1939, no larvae at all were caught (the numbers of hauls, in all areas, were 126 and 133, respectively). During the corresponding summers, however, considerable amounts of 0-Gr. whiting were taken in the Belt Sea: in 1936 2.4 specimens were taken per 30 minutes' haul (total 68 hauls), in 1939 3.0 specimens (69 hauls). This supports the opinion advanced by E. M. Poulsen (l. c.) that the size of the stock of whiting in the inner waters is independent of the inflow of larvae in spring, but to a much higher degree on the immigration of 0-Gr. individuals later in summer. It will be shown in this paper that there must also be a very considerable immigration of I-Gr. individuals.

IV. The age composition of the stock.

A great deal of the material at hand was determined to age by means of scales and otoliths. However, by far the greater part of the material, especially of the 0- and I-Gr., was determined to age by means of the measuring method, which in the case of the said two groups gives fairly safe results. In all 11,912 age determinations were carried out. The results of these determinations are given in table 2. In order to examine whether there is any difference between the age composition of the stock of the inner waters and that of the areas situated closer to the spawning places a distinction has been made between a northern area including the Skagerak and the Northern

Table 2. Age composition of the stock of whiting in Danish waters.

Gr.	Northern area			Southern area		
	Number	sum	per cent.	Number	sum	per cent.
0.....	2926	..	48.4	2893	..	49.2
I.....	2536	5462	90.4	2289	5182	88.2
II.....	480	5942	98.3	441	5623	95.7
III.....	85	6027	99.8	136	5759	98.1
IV.....	14	6041	100.0	94	5853	99.7
V+...	0	..	..	20	5873	100.0
Total...	6041	..	..	5873	..	..

Kattegat down to the line Fornæs—Anholt, and a southern area including all waters south of this line.

It appears from the table that the age groups 0 and I dominate in both areas and together constitute 90.4 and 88.2 per cent., respectively, of all individuals examined; in both cases the 0-Gr. represents nearly half the material (48.4 and 49.2 per cent., respectively). This means that when the individuals have reached an age between 2 and 3 years nearly all of them leave our waters again in order to go to the spawning places. As regards the distribution of the older age groups II—IV it will be seen that there seems to be more older individuals in the southern than in the northern area. The III-Gr. for instance is represented by 136 individuals in the southern and by 85 in the northern area, the figures for the IV-Gr. being 94 in the southern, 14 in the northern area. 20 V-Gr. individuals occurred in the southern, while none of this group were found in the northern area. The cause of this difference is perhaps that the stage of maturity is reached somewhat later by the individuals of the southern area. It must be noted, however, that the number of individuals examined is comparatively small, so that the difference is perhaps accidental.

V. The growth of the whiting.

In table 3 we find the results of all length measurements carried out. Every month is tabulated separately, and the individual age groups are also kept apart. In order to examine whether there is any difference of growth in the various areas a distinction is also made here between a northern area including the Skagerak and the Kattegat north of the line Fornæs—Anholt and a southern area south of this line. It is seen that only the months May—October are included in the table. In the case of the 0-Gr. the time is even limited to the months July—October

because the individuals before this time are so small that a great deal of them will even escape from the small-meshed eel seine, so that the catch will only give an incorrect picture of the size distribution of the 0-Gr. in early summer. The mean length was calculated for each group, and the graphs of figure 2 were plotted on the basis of these figures. It is seen that the 0-Gr. in July in the northern area has a mean length of 8 cm, in the southern area of about 7.2 cm. So there is a distinct difference between the two areas. This difference continues throughout the first period of growth, and the picture does not change until the individuals have reached an age of well above 1 year: now the mean length of the individuals from the southern area is a little higher than that of the population of the northern area. In the III-Gr. the picture changes once more, but the number of individuals measured is now so small, that no great importance can be attached to the difference. In the case of the younger groups we thus find the same state of things as with the cod, in which E. M. Poulsen, 1931¹⁾, found a decrease of growth in all age groups from the Skagerak towards the Baltic.

It will be noticed that the III-Gr. there is a distinct tendency to a decrease of mean length in the course of summer. As mentioned the material from this group is unfortunately rather small, and this is undoubtedly the cause of the irregular run of the graph; but if we look at the mean lengths of both the northern and the southern area as a whole, it will be seen that the growth increase is extremely small in the months May—July, and in August there is even a decrease in mean length of nearly 1 cm:

Month	May	June	July	August
Mean length.....	29.29	29.44	29.55	28.61

The cause of this decrease in mean length is possibly that the bigger individuals of the age group reach the stage of maturity and begin to emigrate towards the spawning places in the Skagerak and the North Sea, so that the age group at this point of time is represented mainly by the smaller individuals. It may further be concluded from the graphs (figure 2) that a considerable increase of length takes place during the period October—May. In October

¹⁾ E. M. Poulsen: Biological Investigations upon the Cod in Danish Waters. Medd. Komm. f. Danmarks Fiskeri- og Havunders. Ser. Fiskeri. Bd. IX. 1931.

Table 3. Ages and lengths of all whiting caught during the fishing experiments with the eel seine in 1930—39. N. stands for the material from the Skagerak and the northern Kattegat down to the mouth of the Limfjord. S. includes all waters south of the Limfjord.

Gr.	May										June									
	0		I		II		III		IV		0		I		II		III		IV	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
4.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
9.....	..	..	5	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
10.....	..	..	16	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
11.....	..	..	17	23	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
12.....	..	..	33	24	..	..	..	..	..	..	..	..	8	6	..	..	..	..	..	..
13.....	..	..	45	48	..	..	..	..	..	..	..	..	11	14	..	..	..	..	..	..
14.....	..	..	59	74	..	..	..	..	..	..	..	..	21	50	..	..	..	..	..	..
15.....	..	..	81	84	..	..	..	..	..	..	..	..	25	76	..	..	..	..	..	..
16.....	..	..	92	64	..	..	..	..	..	..	..	..	25	91	..	..	..	..	..	..
17.....	..	..	83	33	..	..	..	..	..	..	..	..	32	72	..	..	..	..	..	..
18.....	..	..	55	16	..	2	..	..	..	..	..	..	32	73	..	..	..	..	..	..
19.....	..	..	19	10	6	4	..	..	..	..	..	..	23	40	..	2	..	..	..	..
20.....	..	..	12	8	9	5	..	..	..	..	..	..	10	18	5	3	..	..	..	..
21.....	..	..	4	5	23	6	..	..	..	..	..	..	13	17	4	7	..	..	..	..
22.....	..	..	3	3	11	12	..	1	..	..	..	..	7	5	6	5	..	1	..	..
23.....	..	..	..	1	18	16	..	1	..	..	..	..	4	..	8	8	..	0	..	..
24.....	..	..	..	1	16	7	..	1	..	..	..	..	1	..	6	3	..	0	..	..
25.....	..	..	..	..	17	10	1	1	..	..	..	..	..	..	1	9	..	0	..	..
26.....	..	..	..	..	14	5	0	0	..	..	..	..	..	..	3	6	..	0	..	..
27.....	..	..	..	..	4	6	2	6	..	..	..	..	..	..	1	2	1	0	..	..
28.....	..	..	..	..	4	4	0	4	..	1	..	..	..	..	2	..	2	2	..	2
29.....	..	..	..	..	1	2	1	2	..	8	..	..	..	..	..	..	2	1	..	3
30.....	..	..	..	..	..	1	2	9	..	4	..	..	..	..	..	..	1	0	..	3
31.....	..	..	..	..	..	1	1	1	..	8	..	..	..	..	..	..	1	1	..	4
32.....	..	..	..	..	..	..	1	2	..	5	..	..	..	..	..	..	2	0	..	..
33.....	..	..	..	..	..	..	0	1	..	2	..	..	..	..	..	..	1	0	..	..
34.....	..	..	..	..	..	..	1	1	..	1	..	..	..	..	..	..	..	1	..	..
35.....	..	..	..	..	..	..	0	..	..	0	..	..	..	..	..	..	..	..	..	..
36.....	..	..	..	..	..	..	2	..	..	1	..	..	..	..	..	..	..	..	..	..
37.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
38.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
39.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
40.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total...	—	—	524	404	123	81	11	30	—	30	—	—	213	462	36	45	10	6	—	12
Average.	—	—	15.34	14.85	23.21	23.59	30.73	28.60	—	30.80	—	—	16.99	16.61	23.06	23.24	29.90	28.66	—	29.75

(to be continued)

Table 3 (continued).

Gr.	July										August									
	0		I		II		III		IV		0		I		II		III		IV	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
4.....	1	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
5.....	5	4	..	..	..	..	..	..	..	..	1	7	..	..	..	..	..	..	..	..
6.....	36	17	..	..	..	..	..	..	..	..	24	65	..	..	..	..	..	..	..	..
7.....	81	11	..	..	..	..	..	..	..	..	91	161	..	..	..	..	..	..	..	..
8.....	83	18	..	..	..	..	..	..	..	..	254	288	..	..	..	..	..	..	..	..
9.....	77	1	..	..	..	..	..	..	..	..	605	312	..	..	..	..	..	..	..	..
10.....	33	2	..	..	..	..	..	..	..	..	600	215	..	..	..	..	..	..	..	..
11.....	10	..	3	3	..	..	..	..	..	..	472	103	..	..	..	..	..	..	..	..
12.....	4	..	11	2	..	..	..	..	..	..	285	40	..	..	..	..	..	..	..	..
13.....	..	..	23	2	..	..	..	..	..	..	92	8	..	1	..	..	..	..	..	..
14.....	..	..	37	17	..	..	..	..	..	..	27	3	9	2	..	..	..	..	..	..
15.....	..	..	70	22	..	..	..	..	..	..	5	2	28	5	..	..	..	..	..	..
16.....	..	..	99	24	..	..	..	..	..	..	0	..	72	14	..	..	..	..	..	..
17.....	..	..	128	34	..	..	..	..	..	..	1	..	105	17	..	..	..	..	..	..
18.....	..	..	133	20	..	..	..	..	..	..	..	..	159	35	..	..	..	..	..	..
19.....	..	..	102	24	..	..	..	..	..	..	..	..	194	42	..	..	..	..	..	..
20.....	..	..	68	20	5	1	..	..	..	..	..	..	180	40	..	..	..	..	..	..
21.....	..	..	35	7	14	3	..	..	..	..	..	..	135	34	4	..	..	..	..	..
22.....	..	..	13	5	26	7	..	..	..	..	..	..	92	36	9	1	..	..	..	..
23.....	..	..	13	5	45	5	..	1	..	..	..	..	47	17	7	8	1	..	..	..
24.....	..	..	6	1	49	4	..	0	..	..	..	..	19	5	15	16	2	..	..	..
25.....	..	..	..	..	38	8	..	2	..	..	..	..	6	3	11	12	1	1	..	..
26.....	..	..	..	..	36	6	..	2	..	..	..	..	..	1	10	13	4	0	..	..
27.....	..	..	..	..	25	5	..	3	..	..	..	..	..	..	15	10	3	4	..	..
28.....	..	..	..	..	4	2	10	1	..	..	..	..	..	..	4	15	9	3	..	..
29.....	..	..	..	..	..	2	7	3	..	2	..	..	..	..	3	3	4	8	..	2
30.....	..	..	..	..	..	0	6	6	..	1	..	..	..	..	1	..	3	2	..	5
31.....	..	..	..	..	..	1	2	2	..	2	..	..	..	..	..	..	5	3	..	2
32.....	..	..	..	..	..	..	1	0	..	2	..	..	..	..	..	..	0	1	..	2
33.....	..	..	..	..	..	..	2	1	..	2	..	..	..	..	..	..	1	1	..	2
34.....	..	..	..	..	..	..	2	2	..	0	..	..	..	..	..	..	..	0	..	1
35.....	..	..	..	..	..	..	1	1	..	0	..	..	..	..	..	..	..	0	..	2
36.....	..	..	..	..	..	..	..	..	..	0	..	..	..	..	..	..	..	0	..	..
37.....	..	..	..	..	..	..	..	..	..	0	..	..	..	..	..	..	..	1	..	..
38.....	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
39.....	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
40.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total...	330	53	741	186	242	44	31	24	—	11	457	1205	1046	252	79	78	33	24	—	16
Average.	7.95	7.19	17.47	17.34	24.17	24.64	29.87	29.87	—	32.45	9.99	9.20	19.29	19.74	24.96	25.71	28.09	29.33	—	31.50

(to be continued)

Table 3 (continued).

Gr.	September										October					
	0		I		II		III		IV		0		I		II	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
4.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
5.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
6.....	..	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7.....	4	54	..	..	..	..	..	..	..	..	..	20	..	..	..	..
8.....	11	203	..	..	..	..	..	..	..	..	..	..	..	..	..	..
9.....	20	302	..	..	..	..	..	..	..	..	..	81	..	..	..	..
10.....	24	300	..	..	..	..	..	..	..	..	..	101	..	..	..	..
11.....	32	199	..	..	..	..	..	..	..	..	..	68	..	..	..	..
12.....	23	104	..	..	..	..	..	..	..	..	..	45	..	..	..	..
13.....	13	26	..	..	..	..	..	..	..	..	..	31	..	..	..	..
14.....	8	13	..	5	..	..	..	..	..	..	..	10	..	1	..	..
15.....	3	7	2	8	..	..	..	..	..	..	..	3	..	2	..	..
16.....	0	2	3	21	..	..	..	..	..	..	..	..	..	3	..	..
17.....	1	..	4	45	..	..	..	..	..	..	..	..	..	3	..	..
18.....	..	..	2	52	..	..	..	..	..	..	..	..	..	3	..	..
19.....	..	..	1	58	..	..	..	..	..	..	..	..	..	4	..	..
20.....	..	..	..	62	..	..	..	..	..	..	..	..	..	2	..	..
21.....	..	..	..	49	..	..	..	..	..	..	..	..	..	5	..	..
22.....	..	..	..	38	..	2	..	..	..	..	..	..	..	11	..	2
23.....	..	..	..	30	..	6	..	..	..	..	..	..	..	14	..	5
24.....	..	..	..	15	..	11	..	..	..	..	..	..	..	7	..	4
25.....	..	..	..	2	..	19	..	..	..	..	..	..	..	8	..	7
26.....	..	..	..	0	..	17	..	..	..	..	..	..	..	1	..	9
27.....	..	..	..	1	..	21	..	6	..	..	..	..	..	1	..	10
28.....	..	..	..	..	..	14	..	4	..	1	..	..	..	2	..	4
29.....	..	..	..	..	..	2	..	8	..	1	..	..	..	..	..	1
30.....	..	..	..	..	..	3	..	15	..	3	..	..	..	..	..	..
31.....	..	..	..	..	..	2	..	8	..	4	..	..	..	..	..	..
32.....	..	..	..	..	..	..	..	6	..	3	..	..	..	..	..	..
33.....	..	..	..	..	..	..	..	4	..	1	..	..	..	..	..	..
34.....	..	..	..	..	..	..	..	0	..	1	..	..	..	..	..	..
35.....	..	..	..	..	..	..	..	1	..	2	..	..	..	..	..	..
36.....	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..
37.....	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..
38.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
39.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
40.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total ...	139	1216	12	386	—	97	—	52	—	18	—	419	—	67	—	42
Average.	11.16	10.25	16.75	19.59	—	26.10	—	30.06	—	31.94	—	10.11	—	21.78	—	26.40

Table 4.

Gr.	Mean lengths in July			Increase per year		
	Iceland	Denm. S.	Denm. N.	Iceland	Denm. S.	Denm. N.
0.....	3.5	7.2	8.0	..	..	..
I.....	18.1	17.3	17.5	ca. 14.5	ca. 10	ca. 9.5
II.....	27.0	24.6	24.2	8.9	7.3	6.7
III.....	39.3	29.9	29.9	12.3	5.3	5.7
IV.....	46.6	32.5	..	7.3	2.6	..

the 0-Gr. individuals of the southern area have a mean length of 10.1 cm. In the following month of May these individuals belong to the I-Gr., which at this time shows a mean length of 14.9 cm, an increment of 4.8 cm. This shows us that the increase in length during this period is considerably higher than during the period May—October, in which it amounts to 2.9 cm. The I-Gr. of the southern area has a mean length of 21.8 cm while the II-Gr. in May has a mean length of 23.6 cm, in other words an increase of 1.8 cm. The II-Gr. in October has a mean length of 26.4 cm, and the corresponding figure for the III-Gr. in May is 28.6 cm; here the increase amounts to 2.2 cm. However, these figures hardly mean that there has been a uniform growth throughout the period from October to May. It must no doubt be

supposed that the whiting, like many fishes of our waters, does not increase its length in the winter months and that the growth, which is found to have taken place during the period October—May, for the most part dates from November and April. From these months, however, we have unfortunately no examinations.

The growth of the whiting was examined in other areas inhabited by this fish. Fulton, 1901¹⁾, published a great number of length measurements of whiting from the east coast of Scotland; but age determinations of the material were not carried out, and so the results cannot be used for a comparison with conditions in this country. Sæmundsson, 1925²⁾, published the results of an examination of about 250 individuals, all of which were measured and determined to age. This material originates from the southwest of Iceland.

In Table 4 the mean lengths in July of the different age groups from southwest Iceland are compared to the corresponding figures from Danish waters. The table further gives the increases per year in the two areas.

The comparison shows distinctly that the increase in length is much greater at Iceland than in the Danish waters. In the I-Gr. we find at Iceland an increase of about 14.5 cm against 10 and 9.5 cm in the Danish waters. The increase of the II-Gr. is 8.9 at Iceland and 7.3 and 6.7 in the Danish waters. The difference is particularly distinct in the III-Gr.: at Iceland the increase is 12.3, in our waters only 5.3 and 5.7, respectively. However, the following 3 factors must be considered: 1. Sæmundsson's material consists of only 250 individuals, and so the found mean lengths are possibly not very correct. 2. The materials from the two areas were not col-

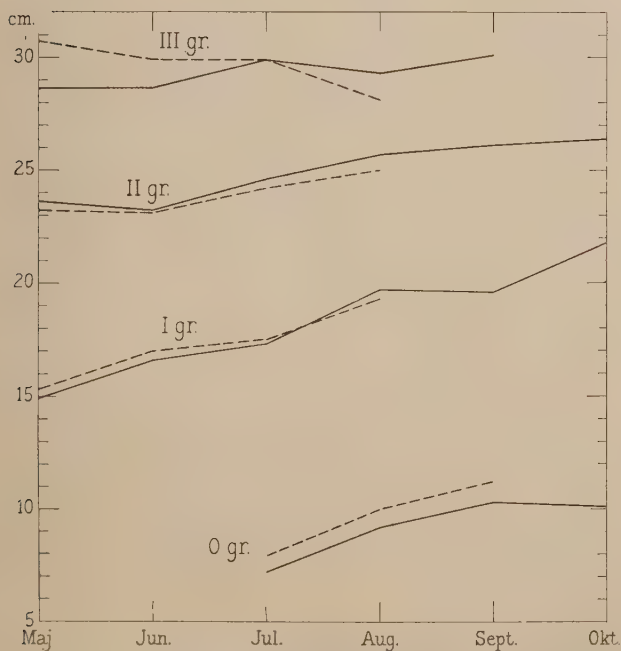


Fig. 2. The growth of the whiting in the Danish waters from 0-Gr. to III-Gr. --- denotes the northern area (N. of the eastern end of the Limfjord), — the southern area (the inner waters S. of the mouth of the Limfjord).

¹⁾ T. W. Fulton: Rate of Growth of Sea Fishes. Fishery Board for Scotland. Vol. 20, Part III. 1901.

²⁾ B. Sæmundsson: On the Age and Growth of the Haddock (*Gadus æglefinus* L.) and the Whiting (*Gadus merlangus* L.) in Icelandic Waters. Medd. fra Komm. f. Havunders. Ser. Fiskeri. Bd. VIII. 1925.

lected with the same gear. As mentioned the Danish material was taken in the eel seine; it is true that Sæmundsson does not mention the gear in which his material was caught, but most likely it originates from the trawl fishery. The mesh-width of the trawl is greater than that of the eel seine, and so the found mean lengths are perhaps higher than those actually applying to the stock. 3. A very important fact is that a great part of the older individuals leave the Danish waters; so it must be considered probable that the mean lengths found in the present material are somewhat lower than the lengths actually applying to the Stock of the Danish waters. Desbrosses, 1948²⁾, has published the results of measurements and age determinations of 589 whiting from the French coast of the Atlantic. By far the greater part of the material was collected from December to April. The author gives the following mean lengths of the different age groups within this period:

I-gr.....	18.5 cm (253)
II-gr.....	25.2 - (58)
III-gr.....	34.0 - (78)

The figures in brackets give the number of individuals measured. It is difficult, however, to compare these results with mean lengths found in Danish waters, primarily because no investigations were carried out in Danish waters during the same months. Another difficulty, which also attaches to Sæmundsson's investigation mentioned above, is that the material was collected in the course of one or some few years, and the growth of the whiting varies highly from year to year as will be shown below. However, the rate of growth seems to be somewhat higher at the French coast than in the Danish waters. In winter for instance the I-Gr. at France has a mean length of 18.5 cm; the corresponding figure for the Danish waters must be somewhat lower, for in May the mean length is only about 15 cm here. The corresponding figures for the II-Gr. are 25.2 and 23.4 cm, respectively.

The growth of the whiting in the Danish waters is subject to great fluctuations from year to year. This is illustrated in table 5, which gives the mean lengths of the 0-Gr. in August and September for the period 1930—39. As will be seen the investigations are

unfortunately incomplete, each month being represented only in 7 years. The figures in brackets give the number of individuals measured:

Table 5.

Year	August		September	
	cm	no.	cm	no.
1930	..		9.51	(142)
1931	..		10.16	(183)
1932	9.94	(444)	9.7	(153)
1933	10.13	(1046)	10.26	(129)
1934	9.47	(241)	..	
1935	10.30	(1142)	..	
1936	..		9.30	(160)
1937	9.02	(219)	9.38	(156)
1938	9.89	(237)	10.16	(431)
1939	8.31	(140)	..	

It will be seen that the mean length in August ranges between 8.3 cm in 1939 and 10.3 cm in 1935. In September the length was found to range between 9.3 cm in 1936 and 10.26 cm in 1933.

A priori one would suppose this variation in the growth to be caused by the varying inflow of salt water from the North Sea into the Danish waters, in other words that a high growth rate would be found in years showing high salinities and temperatures in the Danish waters and a low growth rate in years with a lower salinity. However, a comparison of the salinity and the temperature with the growth seemed to show that no correlation could be traced in the present material. In the case of certain fishes it has been established that the growth is slower in years with a large stock; on the other hand a more rapid growth is observed in individuals belonging to a less numerous year-class. In the whiting of the Danish waters, however, no connexion was found to exist between the quantity of the year-class and its growth.

The biggest individual caught was 40 cm long and belonged to the V-Gr. The oldest individual was 9 years old and had a length of 35 cm. One individual was 8 years old and 36 cm long, another belonged to the VII-Gr. and was 38 cm in length. These 4 individuals were all caught in the southern Kattegat or the Belt Sea.

VI. The occurrence of the whiting in the Danish waters.

As mentioned above the whiting occurs everywhere in the Danish waters though its frequency decreases

¹⁾ P. Desbrosses: Le Merlan (*Gadus merlangus* L.) de la cote française de l'Atlantique. II partie. Rev. Trav. Off. des Pêches. XIV. 1948.

towards the Baltic. This appears most distinctly from the following figures, which represent the numbers of whiting caught per 30 minutes at all depths in the years 1927—39:

Kattegat	Belt Sea	Baltic
20.8	5.8	0.9

It is seen that the Belt Sea contains only about $\frac{1}{5}$ of the number of whiting caught in the Kattegat, and for the Baltic the corresponding figure is about $\frac{1}{20}$.

In the Danish waters the whiting is found both in quite shallow water and in the deepest areas, but there is a distinct difference of frequency at the various depths. This appears from table 6, which for the different areas gives the number of whiting caught per 30 minutes in 1927—39 at the depths stated:

Table 6.

m	Kattegat	Belt Sea	Baltic	Mean
0—14....	10.0	3.7	1.3	5.0
15—24....	15.8	4.9	0.7	7.1
25—34....	21.0	11.6	1.0	11.2
35+.....	44.8	4.4	0.7	16.6

If we look at the mean values for the 3 areas dealt with we note that the frequency of the whiting rises rapidly with the increasing depth: at the stations situated inside the 15 m curve 5.0 whiting were taken

per 30 minutes, but outside the 35 m curve the number per 30 minutes is 16.6. If we take each area separately, we find a few exceptions from this rule. In the Kattegat the stock increases constantly with the rising depth, but in the Belt Sea the highest frequency, 11.6 per 30 minutes, occurs in the areas between 25 and 34 m depth, while the areas of more than 35 m depth gave only 4.4 specimens per 30 minutes; it should be noted, however, that here we have comparatively few fishing experiments from above 35 m depths. The same state of things is found in the Baltic: here the number of whiting taken per 30 minutes at 25—34 m depth is 1.0, the corresponding figure from areas of more than 35 m being 0.7. There is in other words a distinct tendency in the whiting to avoid the deepest areas of our inner waters. It further appears that the whiting in the Baltic seems to be more frequent in shallow water (0—14 m) than in the deeper water layers. It should be noted, however, that the number of stations in all depths of the Baltic is comparatively low, and so these results may be due to accidental circumstances.

VII. The annual changes in the size of the stock.

The stock of whiting in the Danish waters is subject to considerable fluctuations from year to year. This will appear from table 7, which gives the numbers of whiting (all age groups) taken per 30 minutes

Table 7. Numbers of whiting (all age groups, 0-Gr., I-Gr.) caught per 30 minutes with the eel seine in the Kattegat, the Belt Sea, and the Baltic between 1929 and 1939.

Year	Kattegat				Belt Sea				Baltic	
	All age grps.	0-Gr.	I-Gr.	No. of hauls	All age grps.	0-Gr.	I-Gr.	No. of hauls	All age grps.	No. of hauls
1927.....	15.7	3.5	7.3	68	1.9	0.2	0.8	44	0.1	53
28.....	17.3	11.1	5.4	42	2.0	1.0	0.5	89	0.6	66
29.....	15.3	9.1	8.2	68	4.1	3.1	0.6	57	0	4
30.....	14.1	1.8	7.1	39	3.2	2.2	0.9	64	0.2	36
31.....	12.7	0.4	7.6	61	2.2	1.4	0.9	93	1.4	20
32.....	47.4	14.1	32.6	41	9.5	8.1	1.4	101	2.2	21
33.....	38.6	30.5	5.2	54	6.5	3.0	2.6	66	0.5	32
34.....	12.3	1.2	9.4	55	3.3	1.6	1.5	68	3.2	30
35.....	27.0	17.9	5.0	64	6.9	0.9	5.8	62	2.4	19
36.....	13.2	1.5	9.9	34	18.8	2.4	13.9	68	0.1	29
37.....	34.4	23.8	5.7	54	5.7	4.1	0.4	64	3.0	39
38.....	17.4	10.2	6.2	61	8.1	6.0	2.0	108	0.5	35
39.....	4.9	1.8	3.2	16	3.7	3.0	0.8	69	0.2	39
Average	20.8	9.8	8.7	..	5.8	2.7	2.5	..	0.9	..

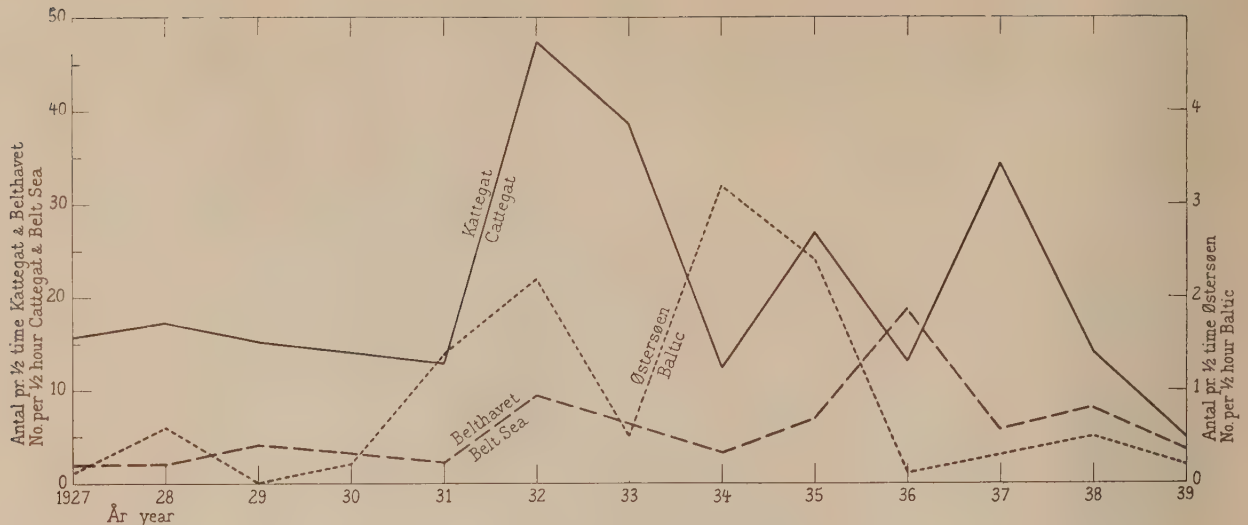


Fig. 3. The yields of whiting (all age groups) caught in the eel seine during the fishing experiments 1927—39 in the Kattegat (———), the Belt Sea (-----) and the Baltic (-----).

in the eel seine during the fishing experiments of the years 1927—39. In the Kattegat the largest number of whiting, 47.4 per 30 minutes, was reached in 1932, 1939 yielding only 4.9 per 30 minutes. In the Belt Sea the richest stock occurred in 1936 when 18.8 individuals were taken per 30 minutes while the year 1927 gave only 1.9 per 30 minutes. In the Baltic 3.2 whiting were taken per 30 minutes in 1934; in 1929 there were none at all, and in 1927 the catches amounted to only 0.1 per 30 minutes. The graphs of figure 3 were plotted from the figures of table 7. They show distinctly that the size of the stock of whiting fluctuates independently in the three areas, the Kattegat, the Belt Sea and the Baltic. If we look at the year 1932, for instance, in which the Kattegat was found to have its largest stock, represented by 47.4 individuals per 30 minutes, 9.5 individuals were taken per 30 minutes in the Belt Sea, which is only about half the amount found in this water in 1936. In this year the Belt Sea gave 18.8 whiting per 30 minutes, the Kattegat only 13.2 whiting. If we look at the conditions in the Baltic, it will be seen that the largest population—3.2 per 30 minutes—was found in 1934, a year in which the populations of both the Kattegat and the Belt Sea were below the mean of the period 1927—39. It has been impossible in the individual years to demonstrate any connexion between the salinity or the temperature and the size of the stock, which is undoubtedly due to the scarcity of the material.

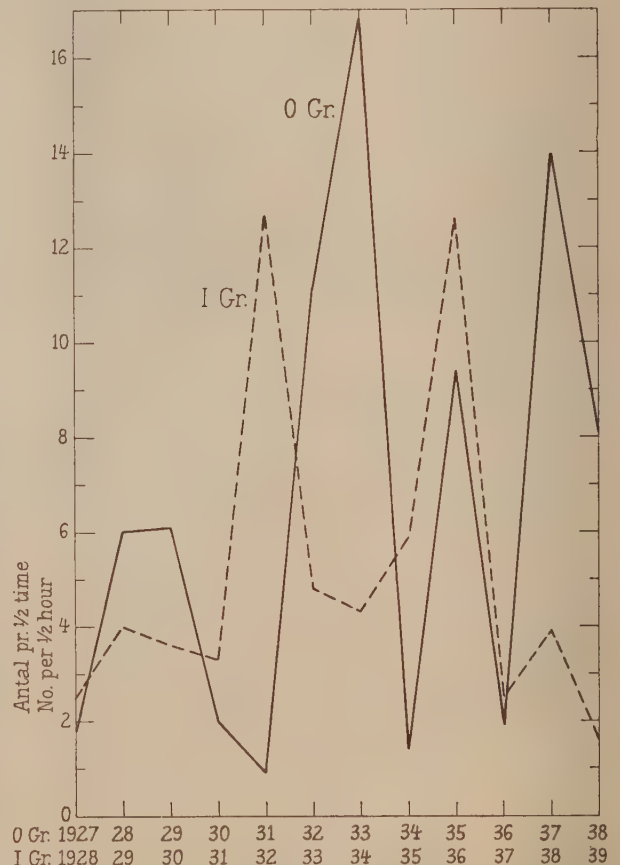


Fig. 4. The yields of 0- and I-Gr. whiting caught in the eel seine, given as means for the Belt Sea and the Kattegat in the years 1927—39.

The table and figure 4 shows the numbers of O- and I-Gr. individuals, respectively, caught per 30 minutes in 1927—39 in the Kattegat and the Belt Sea. In both age groups there are very considerable fluctuations from year to year. It was mentioned above that there is an inflow of individuals of the O-Gr. in spring and early summer. It now appears from the graphs that in most years there is no connexion between the amount of O-Gr. individuals in one year and of I-Gr. individuals in the next. A few examples will illustrate this: in the summer of 1931 the stock of O-Gr. whiting in the Belt Sea and the Kattegat was very small—the result of the fishing experiments was 0.9 per 30 minutes; in spite of this the yield of the I-Gr. in the following year, 1932, was very great, 12.7 per 30 minutes. In other words there must have been a very considerable immigration of whiting during the intermediate period. On the other hand 1933 showed a large stock of O-Gr.—16.8 per 30 minutes—but still the stock of I-Gr. individuals was comparatively small in 1934, being only 4.3 per 30 minutes. In other years, however, a correspondence is observed: the O-Gr. of 1936, for instance, gave 1.9 individuals per 30 minutes; in the following year, 1937, the stock of I-Gr. was 2.5 per 30 minutes. Consequently, the size of the stock of whiting in the Danish waters is determined not only by the immigration of larvae and young individuals of the O-Gr. in spring; probably also at other seasons there is a very extensive exchange of both O- and I-Gr. individuals between the inner Danish waters and the Skagerak and the North Sea.

It was mentioned above that a considerable rise in the yield of the fishery has taken place during the period 1927—48. It further appears from the graphs of figure 3 that an increase of the stock of whiting in the Danish waters has taken place during the period 1927—39. The difference is particularly distinct if we compare the period 1927—31 with the period 1931—39. If we now concentrate the yields of the fishery and the yields of the fishing experiments into averages of periods of 3 years, this rise will present itself very distinctly, both in the yield of the fishery and in the experimental fishing as will appear from table 8.

For each of the four 3-years' periods this table gives the mean yield of the fishery in all Danish waters and the number of whiting taken per 30 minutes during fishing experiments in the Kattegat and the Belt Sea.

Table 8.

	Yield in 1.000 tons	No. per 30 minutes	Salinity in per mille	
			Schultz' Grund. 26 m	Anholt Knob. 28 m
1927—29...	0.33	9.4	30.3	31.9
30—32...	0.93	14.9	31.3	33.2
33—35...	2.23	15.7	30.8	33.1
36—38...	4.05	16.3	31.2	32.8

The table tells us that the yield of the fishery rises from 330 tons in 1927—29 to more than 4.000 tons in 1936—38. At the same time the yield of the experimental fishery rises from 9.4 in 1927—29 to

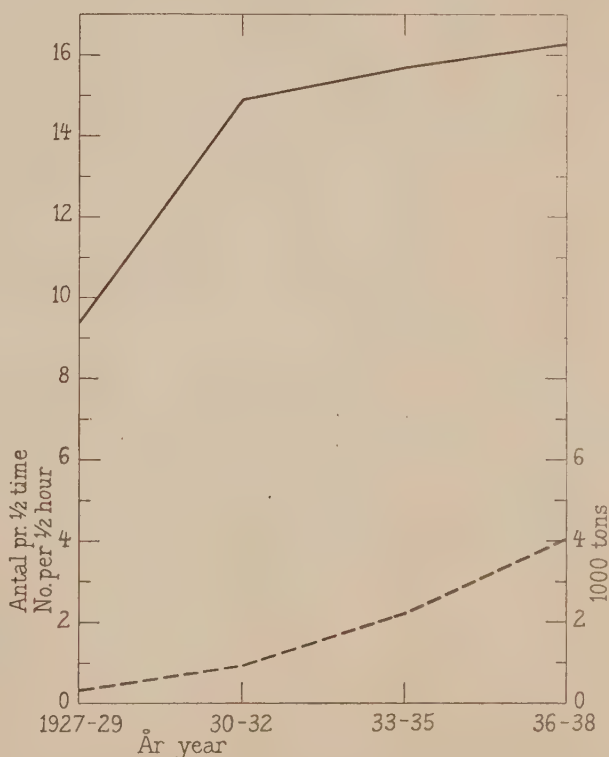


Fig. 5. The full graph shows the yields of whiting per 30 minutes' fishing experiments in the Kattegat and the Belt Sea, given as means of periods of 3 years. The dotted graph gives the yield in 1.000 tons of the commercial fishery in all Danish waters, likewise as means of periods of 3 years.

16.3 in 1936—38. The rise further appears from the graph in figure 5, which is based on the figures given above.

It was mentioned above that a connexion between the salinity (or temperature) and the size of the stock cannot be demonstrated for the individual years. One would expect to find that the increase of the

stock in the Danish waters must be due to a change in the hydrography of these waters, resulting in a rising immigration of young whiting from the North Sea and the Skagerak. H. Brattström, 1941¹⁾, has shown that in the deeper water layers the salinity has increased both in the Kattegat and the Belt Sea. Also this rise of the salinity appears from table 8; it is given as means of 3-years' periods at the two localities Schultz' Grund light-vessel (in the south-westernmost Kattegat) and Anholt Knob light-vessel (in the central Kattegat). It will be noticed that the salinity, which for the period 1927—29 averages 30.74 per mille at Schultz' Grund, for the period 1936—38 has risen to 31.2 per mille. A corresponding rise took place at Anholt Knob. Accordingly, there can hardly be any doubt that the increase of the stock of whiting in the Danish waters is due to an increasing inflow of salter water from the North Sea.

VIII. Conclusion.

The present investigation illustrates certain sides of the biology of the whiting in the Danish waters, and the principal results can be summarized in the following way.

1. The stock of whiting in the Danish waters principally consists of young individuals. Altogether the 0- and I-Gr. make up about 90 per cent. of the stock.

¹⁾ H. Brattström: Studien über die Echinodermen des Gebietes zwischen Skagerrak und Ostsee. Undersökningar över Öresund. Vol. XXVII. 1941.

2. The growth of the whiting is possibly slower in the Danish waters than in other areas examined (Iceland, France). But as possibly the biggest individuals of the somewhat older age groups (II-Gr. and older) leave the Danish waters, it is impossible to get a quite reliable picture of the growth of these age groups.

3. The growth of the 0-Gr. differs very much from year to year.

4. The density of the stock decreases highly from the Kattegat towards the Baltic.

5. The stock increased very much during the period 1927—38, which appears partly from the great rise in the yield of the commercial fishery, partly from the increasing amount of whiting caught during the fishing experiments of the Biological Station. This increase of the stock is probably due to the rise of the salinity in the Kattegat and the Belt Sea during the same period.

However, the present research has not solved all problems involved in the biology of the whiting in the Danish waters. Very important questions have not yet been answered. Such a problem is for instance the origin of the whiting occurring in the Danish waters. Do they come from the spawning areas of the Skagerak of the North Sea or possibly from both of these areas? This question can only be answered by researches upon the racial conditions of the whiting and by marking experiments. Investigations of this kind have not yet been carried out in the Danish waters.

Investigations on the Biology of the Oyster XII.
On the Fluctuations in the Oyster Stock of Northwestern Europe.

By
R. SPÄRCK

IN the years about 1921 an apparently sudden and enormous decrease occurred in the English stock of native oyster. According to the statistics given by Cole (1949) the English production of native oyster fell from 39.4 mill. oysters in 1920 throughout the twenties (1923: 18.1 mill., 1927: 9.7 mill.) until a minimum was reached in 1930 with 6.9 mill. In the thirties there was a rise, culminating in a maximum of 19.2 mill. in 1936, after which the yield went down once more, especially after the severe winters in the beginning of the forties. In 1944 the yield was 4.5 mill.; since then there has been a slight rise, and the present production is about 6—7 mill. The decline was not equally great in the individual localities of production. As will appear from Cole's tables the decrease was particularly great in the River Blackwater where the production fell to $\frac{1}{10}$ between 1918 and 1923, after which time it never rose to more than a few hundred thousands though it was 10.1 mill. in 1918. In the Upper Fall the decrease was much more slowly; as late as 1921 the yield amounted to 16 mill. The minimum occurred in 1929 with 100 000; since then there has been a steady rise, the production of the latest years being 1.5—1.7 mill.

Though it appears from Cole's paper that the English statistics contain certain errors, the trend of the development is so obvious and distinct that the production of oyster on the English natural beds must indisputably be said to have fallen rapidly from about 1918—20 towards 1930 when another slight rise occurred, a rise which in some localities was interrupted by another fall caused by the ice-winters of 1939—42. In some places the decrease of the twenties seems to have been completely steady while in others it started rather suddenly. It is well-known that the fall of the English oyster stock about 1920 by practitioners was put down to the submerging of various explosives etc. after the first world-war. No doubt this view still prevails among practitioners, but there is no proof at all of its correctness, and the investigations undertaken by Orton (1924) gave absolutely no indication that these explosives could

be responsible for the decrease of the stock—on the contrary, Orton rejects the possibility of it. Cole, who in his said paper from 1949 once more touches on the question, is inclined to ascribe the decrease and the so-called mortality to an unknown epidemic or disease and rejects the supposition advanced from elsewhere that the said decrease of the oyster population must be considered the result of an infavourable change in the ecological factors.

It is true that the said decrease of the English oyster population, considered as an isolated phenomenon, may seem to be inexplicable—however Orton points out that the mortality was not so enormous and sudden as was otherwise maintained. But if we look at it in connexion with the fate that befell the other oyster populations of northwestern Europe during the very same period, it seems to me that the picture changes. The figures given by Havinga (1949) for the yield of the Dutch oyster fishery illustrate a quite corresponding situation. In 1912 the yield was 3 mill kg, in 1925 it had fallen to 1.3 mill.; another rise was followed in the beginning of the thirties by an enormous fall, which here, however, was caused by special conditions (the shells disease). The fishery at Sleswick, the yields of which were published by Hagmeier in 1926, shows exactly the same picture as in England and Holland—a rising yield during the years between 1910 and 1920, culminating in an annual fishery of 850 000 pieces; in 1922—23 an enormous decrease begins, and after the yield has fallen to 118 000 pieces in 1924—25 the fishery stops.

Finally, the fishery in the Limfjord shows exactly the same picture. In 1910—20 the yield is very high (1915—16: 5—6 mill. pieces; 1916—17: 4.7 mill.; 1919—20: 4.7); then it falls rapidly to the minimum of 490 000 in 1924—25, at which time the fishery ceases.

If we now compare the yields of these four fisheries of northwestern Europe, it is quite obvious that the picture is precisely the same: a high and rising yield between 1910 and 1920, after which time a more or less violent fall begins everywhere. In some localities

the minimum occurs already in the middle of the twenties, on the English beds not until about 1930. We are here dealing with four separate areas, which at that time (at any rate as far as the Sleswick waddensea and the Limfjord are concerned) had no connexion inter se in the form of import of spat, etc., and so there can hardly be any common epidemic cause, much the less so because the character of the mortality showed no indication at all of infection or parasites. As already demonstrated by me (1924, p. 75 and 1925) the remaining possibility is to find the cause in the variation of the ecological conditions, more especially in the climatic conditions which broadly speaking vary in the same way within the four areas.

As demonstrated for the Limfjord (Spärck 1924 and 1949) there is a close connexion between the fluctuations in the oyster population of the Limfjord—and hence in the yield of the fishery—and the climatic conditions, in the first line the summer temperature. It is the summer temperature, on a closer view the mean temperature of the warmest month, that must be considered the principal regulating factor in the fluctuations of the stock. A rise in the oyster population of the Limfjord was observed only during periods in which a number of warm summers followed closely upon each other. On the other hand, periods in which the mean temperature of the surface water during the warmest month was below 17—18° C. for several successive years gave a decreasing oyster population. As already emphasized these fluctuations, brought about by the summer temperature, are comparatively smooth. Everywhere in western Europe we had a comparatively large stock of oyster about 1910, and this must be put down to a number of warm summers about 1910. In 1925—30, however, we had a small stock of oyster everywhere in western Europe; this must be laid down to the fact that the summers of the years between 1914 and 1930 generally speaking were cool. At present the natural stock of oyster once more shows an increase—in the localities where this is possible; this must again be ascribed to a series of warm summers during the period 1937—47.

The size of the stock of oyster is of course not determined exclusively by the summer temperature, but for the stocks living near the temperature limit of the species—which is true of all four stocks of northwestern Europe, more particularly the stocks

of the Limfjord and West Sleswick—the summer temperature must undoubtedly be considered superior among the factors that are responsible for the great fluctuations with periods of several years. Also the winter temperature may come in, but its effect is generally more limited and will mostly consist in an increased mortality in a few severe winters, more particularly during the period 1939—42 when this increased winter mortality counter-acted the increase of this very period, caused by the high summer temperatures. However, a look at the fluctuations of the stock of oyster during the later decennia shows that the influence of the winter temperature generally speaking is much inferior to that of the summer temperature.

The nutrition is a third factor, the importance of which in my opinion is often underrated. That oysters in basins, tanks, the Norwegian creeks and in similar limited bodies of water may die from lack of nourishment was emphasized by me in several earlier publications (1924, pp. 74—75; 1926; 1927). Also in nature, for instance in the Limfjord, we now and then observe a summer mortality that must no doubt be put down to lack of nourishment. In the first place the look of the oyster during these summer mortalities is precisely the same as when the mortality occurs from lack of nourishment in basins, tanks, etc. The animals have no stomach contents, the crystalline style disappears, the digestive gland ("*hepatopancreas*") blanches, and a slowly advancing paralysation of the adductor muscle sets in. Secondly this form of mortality is particularly frequent in localities with a dense stock of oyster (notably among relayed oysters) or where the temperature in summer reaches particularly high values, for instance in quite shallow water during sunny periods, more especially in localities with slow movements of water. In my opinion too little weight is attached to this summer mortality in the literature on the oyster. On the Dutch and English oyster beds where the stock as a rule is much denser than on the Limfjord beds, which is possible on account of the considerable renewal of water caused by the tide, the situation may no doubt arise that a sudden heat intensifies the food requirement of the oyster to such an extent that the production of nourishment proves insufficient. In England the summer of 1921 is said to have had such a short hot period. To me it therefore seems needless at present to introduce the idea of mystical diseases or epidemics in the

stock of oyster when such a summer mortality sets in. It is fully legitimate to consider it a result of lack of nourishment alone. The great decrease of the English oyster population during the years about 1920 is totally coincident with the general decrease all over the European stock, possibly to some extent

emphasized by a particularly conspicuous summer mortality in 1921, and the causes must no doubt be the changes in climate and ecological conditions that form the background of the great fluctuations in the oyster stocks of northern Europe.

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On the Distribution of the Slipper-limpet (*Crepidula fornicata*)
in Danish Waters.

By
R. SPÄRCK

IN 1934 the occurrence of *Crepidula fornicata* was established in Nissum Bredning in the western part of the Limfjord (Späreck 1935). The first specimens of *Crepidula* were found near localities where large amounts of Dutch oyster spat had been relaid during the previous 10 years, and so there can be no doubt that *Crepidula*—as pointed out earlier—must have been brought into the Limfjord with Dutch oysters. As was expected *Crepidula* has spread over the whole Limfjord during the last 15 years. Already in 1940 *Crepidula* was found in Livø Bredning, and during the following years it has spread, so that now it must be said to occur practically everywhere in the Limfjord where its empty shells are very frequently found to have been washed ashore. Especially the warm years 1943, 45 and 47 seem to have increased the stock, for after these summers a considerable number of small *Crepidula* was observed. Although *Crepidula* must therefore now be characterised as frequent everywhere in the Limfjord, its frequency is nowhere so great that a noxious influence of essential importance on the oyster fishery can be stated. The period during which the spreading and increase of *Crepidula* took place in the Limfjord coincides with a period in which the natural stock of oyster showed a considerable rise and the yield of the oyster fishery on the whole was increasing. The cause of these is to be found in the fact that the oyster beds of the Limfjord—both the natural and the artificial ones—in contrast to the beds of the English and Dutch tidal coasts are so large that apart from the oysters they also contain a rich fauna of other bivalves together with shells, stones, etc. in considerable quantities. Therefore the oysters make up a comparatively small percentage of the possibilities of attachment for *Crepidula*, and this must be the reason why the oyster of the Limfjord to a comparatively small extent only is set with *Crepidula*.

During the 15 years, however, that have elapsed since *Crepidula* was observed for the first time in the Limfjord it has turned out to be present in two other localities of Danish waters. During some

dredgings in the waters at Esbjerg in May 1948 the present author found two living specimens of *Crepidula* partly in the channel SE. of Sønderho on Fanø, partly in the channel off the harbour of Esbjerg—both at a depth of 5–6 m on stony or gravelly bottom. So there can be no doubt that *Crepidula* is about to immigrate into the Danish waddensea. Some years ago *Crepidula* was carried into the German waddensea about Før and Sild with Dutch oysters (Hagmeier 1941), and it is not surprising that from these localities it has spread towards the north and has now reached the waters round Esbjerg. Here, however, the stock is still quite small as compared to the stock of the Limfjord¹). Dead shells were found in 1942 at Rømø (Zool. Mus. of Copenhagen), in 1946 at Højer (Nat.-hist. Mus. of Århus) and in 1949 at Hvide Sande (Zool. Mus. of Cop.).

In the same year in which the first find of *Crepidula* was made in the Danish waddensea a small specimen was found on the 14-fathom reef off Frederikshavn during a University course of marine biology. During another course in 1949 some *Crepidula*, attached to *Pecten opercularis*, were taken on Herthas Flak in the northwestern Kattegat. Besides in this locality *Crepidula* was found again off Frederikshavn at about 8 m depth, 2 individuals on the top of each other on a shell of *Macoma calcaria*. Finally, the Zoological Museum has received some empty shells, which were found to have been washed ashore at Gammel Skagen; these shells are comparatively large and originate from individuals that must be supposed to be at any rate 4–5 years old. After this there can be no doubt that a stock of *Crepidula* is living in the northwestern Kattegat in the water between Frederikshavn and Skagen where, unlike the occurrences in the Limfjord and the waddensea, it seems to live in comparatively deep water of 8–30 m depth. The origin of the stocks in

¹) A shell found in the bay of Århus in 1941 (the Nat.-hist. Mus. of Århus) must be supposed to originate from ballast or the like because no other indications of an occurrence of *Crepidula* were found here.

the Limfjord and the waddensea cannot be discussed, but the origin of the stock of the northern Kattegat is more dubious. It may have been introduced with ballast or the like in Dutch ships, of which many are sailing in Danish waters, but it seems more likely that a natural immigration has taken place, presumably starting from the Limfjord where there is now a large stock of wide distribution. It is of course possible that it has immigrated along the west coast of Jutland and round Skagen like *Petricola*

pholadiformis, but this seems to be less probable, for in this case there must be a stock in the North Sea off the west coast of Jutland, and such an occurrence would have made itself known by washed-up shells on the shore. We have no information on such finds, which can hardly be due to an oversight because finds of *Crepidula* generally attract attention. So there is every probability that the Kattegat stock of *Crepidula* originates from the stock of the Limfjord.

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